MINING engineering

SEPTEMBER 1956

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MINING engineering

VOL. 8 NO. 9 SEPTEMBER 1956

COVER

This month cover artist Herb McClure dramatizes the role played by the host of mineral materials that enter into the construction and operation of the modern nuclear reactor. **For more of the story turn to page 904.**

FEATURES

ARTICLES

TRANSACTIONS

PERSONNEL

THE following employment items are made available to AIME members on a non-profit basis by the Engineering Societies Personnel Service, Inc. (Agency) operating in cooperation with the Four Founder Societies. Local offices of the Personnel Service are at 8 W. 40th St., **New York 18;** 100 Farnsworth Ave., **Detroit;** 57 Post St., **San Francisco;** 84 E. Randolph St., **Chicago 1.** Applicants should address all mail to the proper key numbers in care of the New York office and include 6c in stamps for forwarding and returning application. The applicant agrees, if placed in a position by means of the Service, to pay the placement fee listed by the Service. AIME members may secure a weekly bulletin of positions available for $3.50 a quarter, $12 a year.

MEN AVAILABLE

Civil or Mining Engineer, B.S. in chemical engineering, 26. Two years hardrock mining, one and one-half years officer in Corps of Engineers; three years bauxite exploration and processing. Desires responsible position with future in mining, construction, or plant engineering fields. Prefer western U. S. or foreign. M-282-San Francisco.

Superintendent or Assistant Superintendent, M.S., 30. Four years ore dressing experience in sulfide minerals. Production and maintenance responsibility. Some flow sheet design and equipment installation experience. Prefer U. S. or foreign. M-281.

Preparation Engineer, B.S. in mineral preparation, 33. Experienced as coal inspector, assistant preparation engineer, draftsman, design, and sales engineer. Experienced in plant layout and design. Was Lieutenant in U. S. Army, commercial pilot. Location, immaterial. M-280.

POSITIONS OPEN

Mining Engineer, with metal mining exploration and development experience for examination and evaluation of copper, manganese, and uranium properties. Must speak Spanish. Salary open. Location, Latin America. F3594.

Chief Mining Engineer, to take charge of all underground mining by shrinkage and stoping, all surveying and layout. Location, Central America. F3579.

Mine Superintendent, for Pb-Zn mine. Salary, $8100 to $8700 a year. Location, Mexico. F3800(b).

Mining Engineers, Geologists, and Metallurgical Engineers, to head up various operations for South American Government. Salary open. F3771.

Geologist, for planning, supervision of geological engineering studies (subsurface) for nonmetallic mine. Salary open. Location, British Columbia. F3752.

General Superintendent, mining, for copper property operating 4000 tpd, surface mining operations. Salary, $15,000 to $20,000 a year plus free housing. Location, Philippine Islands. F3751.

Engineers. a) *Geologist,* to teach paleontology, stratigraphy, physical geology, petroleum geology. One year contract; may lead to permanent position in teaching or research. Will consider advanced graduate student desiring teaching experience and/or thesis material. Rank and salary open. Starts September 1956. b) *Mining Geologist,* to make investigations of mineral commodity resources as part of long range program evaluating state's potentialities. Unusual opportunity for man with experience in examining mineral deposits and background in mineral economics. Salary open. Location, West. W3721.

Mine Superintendent, graduate mining engineer, with from eight to ten years experience for lead, zinc, silver mine in Central America. Must speak Spanish. Salary open. F3709.

Chief Geologist, with eight to ten years experience in mine and exploration geology required, some of it in Latin America, to supervise geological work of mine development program and head up general exploration. Knowledge of Spanish essential. Contract. Salary open. Location, South America. F3705.

Chemist and Chemical Engineer. a) *Chemist,* with from none to ten years experience, to perform basic and applied research for development of new or improved methods for recovery of uranium from ores. Background in organic and physical chemistry desirable. Salary open. b) *Chemical Engineer,* with from none to five years experience, to perform laboratory and semiwork scale development studies on new processes for recovery of uranium from ores. Work will include equipment design and layout. Background in solvent extraction helpful. Salary open. Location, vicinity of Boston. W3758.

Mining Engineer, with metal mining exploration and development experience for examination and evaluation of copper, manganese, and uranium properties. Must speak Spanish. Salary open. Location, Latin America. F3594.

Chief Mining Engineer, to take charge of all underground mining by shrinkage and stoping, all surveying and layout. Salary open. Location, Central America. W3579.

BOOKS

ORDER THE FOLLOWING BOOKS THROUGH AIME— Address Irene K. Sharp, Book Dept. Ten percent discount given whenever possible.

Foundation Engineering, by Rolt Hammond, *Philosophical Library*, $10.00, 188 pp., 1956.—An illustrated survey of modern foundation problems and their solution with attention to soil mechanics, site exploration, piled foundations, vibration-controlled foundations, and the foundation problems encountered in specific structures such as bridges, houses, etc.

Coal Production in the U. S. A. by Companies, for the Year 1955, by Coal Mine Directory, *McGraw-Hill Publishing Co.*, $5.00, 1956.—A complete guide to names, locations, and equipment of every company with a production of over 100,000 tons in 1955.

The Economic Almanac 1956, edited by F. W. Jones for the National Industrial Conference Board, *Thos. Y. Crowell Co.*, $3.95, 688 pp., 1956.—The mining section of this factual handbook of business, labor, and government includes statistics on production, consumption, imports, exports, mineral product values, operating ratios, etc.

The Evolution of the Igneous Rocks, by N. L. Bowen, *Dover Publications Inc.*, $3.75, 322 pp., 1956.—An interpretation of the diversity of igneous rocks in terms of fractional crystallization, with emphasis on the physical chemistry underlying geology.

Please Order These Publications from the Publishers

Mining Directory of Minnesota, 1956, by Henry H. Wade and Mildred R. Alm, *Mines Experiment Station*, University of Minnesota, Minneapolis, $1.00, 277 pp.—A list of all operating companies and major holding organizations identified with Minnesota iron ranges, together with officials, subsidiary and affiliated companies, as well as pertinent information, general statistics, and maps.

The Asbestos Industry, by Oliver Bowles, *U. S. Government Printing Office*, Washington 25, D. C., $1.00, 110 pp., 1955.—A comprehensive report on the asbestos industry, with reference to distribution, production, consumption, mining and milling processes, beneficiation, and synthesis of the mineral throughout the world.

Please order the following from: *State Bureau of Mines and Mineral Resources*, **Campus Station, Socorro, New Mexico.**

Geology of Costilla and Latir Peak Quadrangles, Taos County, New Mexico, Bulletin 42, by Philip F. McKinlay, $1.75, 32 pp., 1956. Prepared in cooperation with the U. S. Geological Survey, this bulletin treats the geography, geology structure and history of the Taos Range of the Sangre de Cristo Mountains and the Costilla Plain. Included are an index map and a geologic map of physiographic subdivisions of Costilla and Latir Peak Quadrangles. The purpose of the survey was to delineate ore mineralization.

Deposit of High-Calcium Lime Rock in Valencia County, New Mexico, Circular 36, by Henry L. Jicha, Jr., free, 5 pp., 1956.—This publication should be of interest to persons concerned with the establishment of a cement plant or chemical industry requiring a high-calcium limestone.

Geology of the Luis Lopez Manganese District, Socorro County, New Mexico, Circular 38 by Alfred T. Miesch, free, 31 pp., 1956.—A geologic map and picture, as well as diagrams and tables, are contained in this concise pamphlet which describes deposits of manganese oxides in the Luis Lopez mining district.

(Illustration from Agricola's De Re Metallica (1621))

All ore processing was difficult 400 years ago

There was a time when the grinding in an ore preparation plant consisted of a man with a hammer—like the one shown here, equipped with heavy leggings and gloves to protect himself against flying ore chips.

Today's ore processing plant is a far cry from this. It utilizes efficient grinding mills that turn out many tons of processed ore every day—mills which so often use CF&I Grinding Balls and Rods. CF&I Grinding Balls and Rods are always made from special analysis steel that has the ideal balance between toughness and hardness to assure optimum grinding ability and maximum wearability.

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CF&I

LETTERS

Dear Sir:

I found the recent papers in the symposium on greater cooperation for metallurgical planning very interesting. I do feel one important point was missed. In order to have good cooperation between geologists, mining engineers, and metallurgists, each must understand the other's field.

The economic geologist deals with ore. The definition of ore is "material that can be mined, and the valuable metal recovered at a profit." Many graduating geologists have little or no background in mining methods and cost, and less knowledge regarding metallurgical processes. This is either because they have had no desire to know or their schooling was so limited. A geologist so equipped cannot appreciate the potential values of a possible ore deposit if he cannot see the general problems involved in mining and treating the ore.

Many elaborate reports have been made by so-called consulting geologists without any regard to the economics of mining and metallurgy of the possible ore. The problem is not limited to consultants; it is heard within large companies: "We find the ore, it is up to the engineers to mine it and the metallurgists to extract the metal, these are not our jobs." This thinking is generally the result of the geologist not realizing and appreciating the problems involved in mining ore and extracting metals.

It is true that the geologist is rather stuck with the ore as he finds it. He cannot change the ore to fit a given mine method or recovery method. He can, however, present all of the geological information to both the engineer and the metallurgist that will help them change their methods to fit the ore. This can best be done if he understands the general principles of mining and metallurgy.

The mining engineer, on the other hand, gets to thinking that his is a job of stress and strain, equations and machines. Let the geologist outline the ore. In many cases he does not know the ore minerals in the mine. He goes by the chemical analyses of the last sample. Structures, to him, are buildings and shafts, and many times he is ignorant of faults and joints that might affect his mining layout. He does not realize the effect of water or the oxidation of broken ore on the metallurgical recovery.

Many geologists and mining engineers, especially in large mining operations, have never been to the mill or extraction plant. This is especially true if such plants are not at or near the mine. The metallurgist is frequently just as limited in his knowledge of the other problems. At times he demands a product from the mine that is not always economical to produce. By properly understanding both the mining and geological problems he can offer suggestions that will produce an economical product.

This is a problem both in education and experience. The person who ends up as co-ordinator of these three fields does so because he has a knowledge of all three and thus, as Reno Sales points out, becomes the manager or some top officer. The co-ordinator has a much easier job if he has men working for him who, through their desire to learn, and with a broad education as a basis, have obtained a knowledge of the other person's problems.

Paul W. Zimmer
Geologist

Dear Sir:

Inasmuch as your front cover artist for the May Issue was so prolific with his roof bolts, he might have continued around the circle and placed some *roof* bolts in the floor.

This floor bolting is used in several of the coal mines in Belgium, and very successfully, as it prevents the floor from heaving.

R. T. Banks
Consulting Engineer
Joy Manufacturing Co.

NOTICE:::

Mining Branch Office has a LIMITED number of the 1956 Annual Meeting Mining Branch Abstract Booklets available for distribution to those who request copies from Arnold Buzzalini, Mining Branch, AIME, 29 West 39th St., N. Y. C. 18. Abstracts of the following divisions are included in this booklet: Mining, Geology and Geophysics Div., Industrial Minerals Div., Mineral Economics Div., and Mineral Industry Education Div. There is no charge for this service. Booklets will be sent out on a first come first served basis.

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XANTHATES: collectors of consistent quality, in pellet form for dustfree handling. Wide range assures high selectivity.

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WHEN a mill's sulfide flotation costs are at rock bottom, chances are you'll find Dow Xanthates and Dowfroth® 250 at work in the recovery process. Carefully compounded for independent collecting and frothing, this pair functions in perfect balance to bring you the highest flotation efficiency known.

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Dow offers a wide range of Xanthates that are substantially nonfrothing, completely and quickly soluble in water. They are designed for selective flotation to assure maximum loading of the froth as ore conditions change. In addition, these superior collectors assure an unusual ease in handling, for the entire series comes in pellet form. No dust, waste, or spillage problems!

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The ideal working partner to Dow Xanthates—or any other *collector*—is Dowfroth 250. It is completely water-soluble also, and produces a froth that's lively over a wide range of conditions. In many cases, Dowfroth 250 reduces frother consumption as much as 75%! Action is rapid and noncollecting, better accommodates ore variation. And froth is easy to launder, pump and thicken; does not deteriorate rubber parts.

Everyone benefits

Flotation experts agree that Dow Xanthates and Dowfroth 250 do much to improve recovery and concentrate grade. The metallurgist has better control of frother and collector. And the operator's work is pleasanter, thanks to the pellet form of Xanthates and the low volatility of Dowfroth 250. Why not write us for samples today and let every member of your flotation team discover the advantages of these dependable mining chemicals!

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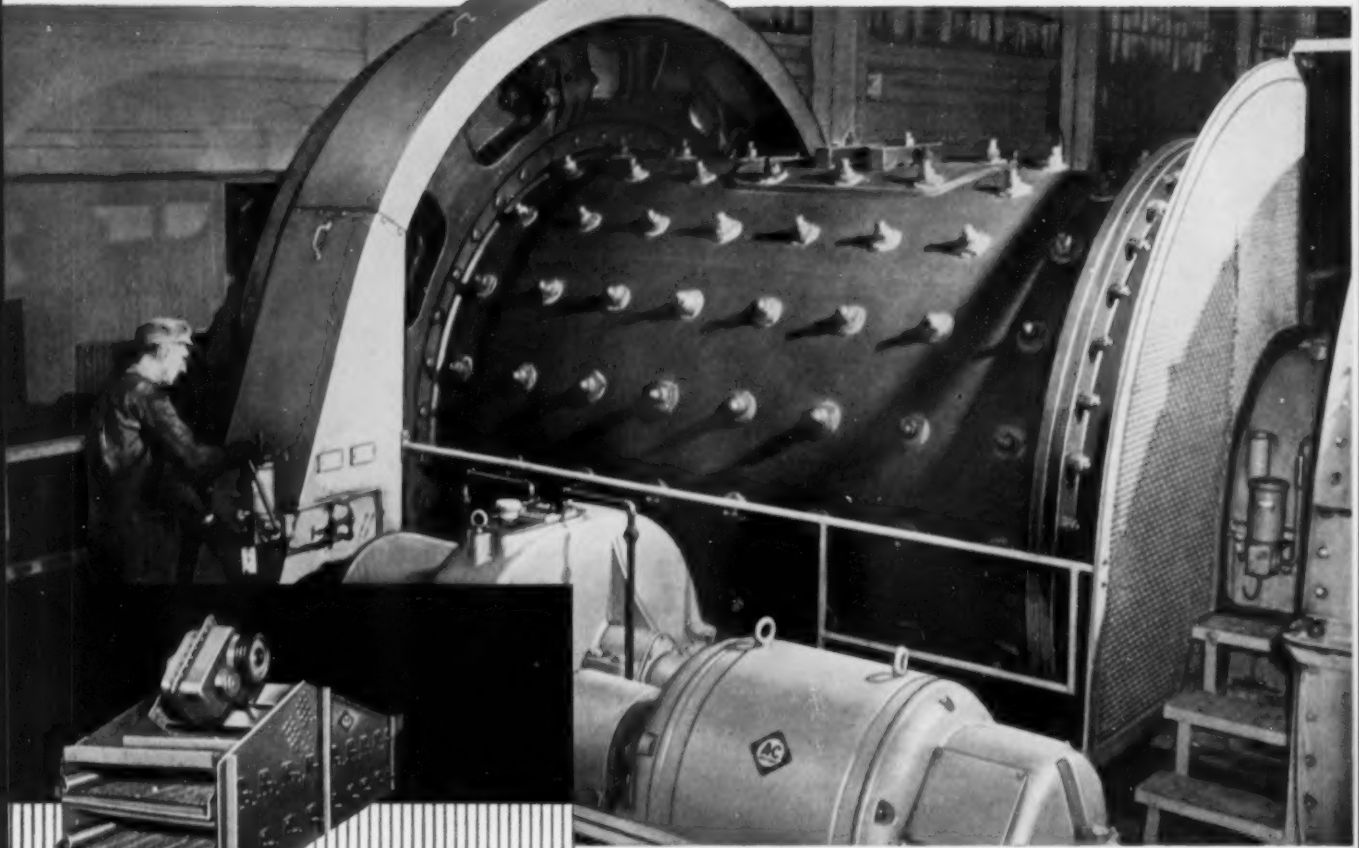
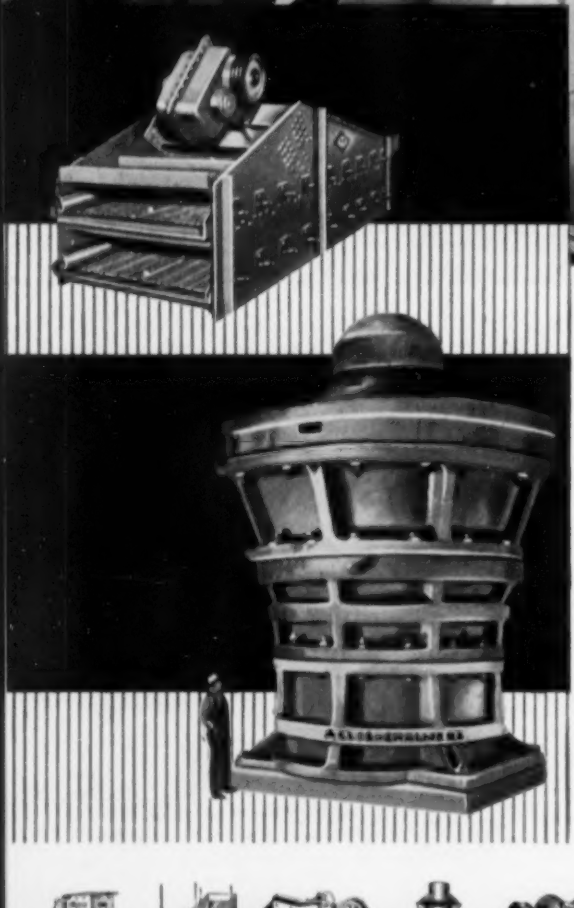


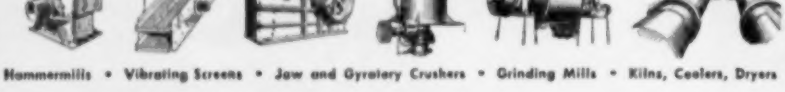


"Coordineered" Equipment for the Mining and Rock Products Industries

GRINDING MILLS—Whether your process calls for individual mills or a grouped stage grinding series, Allis-Chalmers can make a right-for-the-job recommendation from seven different types of grinding mills.

VIBRATING SCREENS—Allis-Chalmers screens are built in single and multiple-deck models for use in scalping, wet or dry sizing, washing, rinsing, dewatering, and media recovery.

GYRATORY CRUSHERS — "One-man, one-minute product control" slashes the time it takes to change crusher setting from hours to seconds. Size adjustment, compensation for wear and emergency unloading are accomplished at the flick of a switch.



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ALLIS-

THIS TRAXCAVATOR* CAN LOAD OUT
450 TONS PER 8-HOUR DAY

THIS CAT* HT4 Traxcavator averages 350 to 450 tons of lead-zinc ore per 8-hour day, working 300 feet underground in a mine at Picher, Okla. It is one of 7 Traxcavators owned by American Zinc-Lead and Smelting Co. on the job. All the machines are equipped with air starters, and with exhaust scrubbers designed and built by head mechanic Bob Boyes.

Now there is a new line of Traxcavators, built to handle even more material at even lower cost. The No. 933 (1-yard bucket and 50 HP), the No. 955 (1½-yard bucket and 70 HP) and the No. 977 (2¼-yard bucket and 100 HP) comprise the new Caterpillar-built Traxcavator line.

These 3 new Traxcavators are compact, maneuverable and easy-handling. Their clean exhaust—thanks to efficient and trouble-free Caterpillar fuel injection—makes scrubbers practical for underground work. In all 3 of the machines, weight, horsepower and bucket capacity are perfectly balanced to give top efficiency and economy.

All 3 have these advanced Caterpillar features: 40-degree bucket tip-back at ground level for more leverage, less spillage. Extra-strong box section bucket arms stand up under heavy loads and shocks. Long-lasting oil clutch, which seldom needs adjustment and stands up to roughest duty. Conveniently placed controls and "built-in" operator comfort mean more production with less effort.

There's a Caterpillar-built Traxcavator, with choice of buckets and attachments to increase versatility, that will cut costs in *your* mine. Ask your Caterpillar Dealer for full details today.

Caterpillar Tractor Co., Peoria, Illinois, U. S. A.

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WILL DEMONSTRATE

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Wetdust Nozzle

Rock dusting up to the working face during shifts is possible with the *Mine Safety Appliances Co.* Wetdust Nozzle used in combination with the Bantam 400 duster. Slurry produced is also a good fire fighting medium. Nozzle is attached with a water line to the Bantam's discharge hose and its fine spray thoroughly wets the dust before it leaves the nozzle. Tip nozzles available are: 1, 1¼, and 1½ in. **Circle No. 1.**

Turbopower Engines

Replacement power in on and off-the-highway trucks comes in a compact package with a choice from the Turbopower engines which have been added to the Series 71 diesels by *Detroit Diesel Engine Div.* of General Motors Corp. Addition of a single-shaft, exhaust-driven turbine and air impeller produce greater fuel economy and more power. A 6-cyl base-mounted power take-off unit is also available. **Circle No. 2.**

Excavator

Latest and largest in the *Koehring Co.* line of shovels and cranes is this model 1205 with a lifting capacity of 95 tons at 75 pct rating. Standard shovel attachment combines a 30-ft boom with 22-ft dipper sticks and a 3 cu yd dipper. Traction brakes are

spring loaded and released by air to help reduce operator fatigue. Total weight of the machine is 179,360 lb when equipped as a standard shovel and 197,015 when equipped as a crane with 60-ft boom. **Circle No. 3.**

Blast Hole Drill

Model 6TA is a new addition to the Portadrill line of truck, trailer, and tractor-mounted drills by *The Winter-Weiss Co.* Two-man operated, the drill mounts on a Cat D6 and utilizes compressed air for cuttings removal. Heavy duty transfer case supplies power taken from the tractor and controls are located for full view of operations. Up to 27,000 lb of weight can be applied to the bit and the drill is said to average a foot or more a minute of 9-in. hole in some formations. **Circle No. 4.**

Vibrating Bar Grizzly

Nordberg Mfg. Co. has the Symons vibrating bar grizzly, a compact heavy-duty scalping unit with capacity up to 1000 tph. Recommended for materials that are wet, sticky, or gummy, the grizzly has powerfully-vibrated manganese steel bars that permit non-clogging operation under adverse conditions. **Circle No. 5.**

Gasoline Powered Rock Drill

Atlas Copco Eastern Inc. offers the gasoline-powered Cobra motor drill and breaker that weighs only 53 lb, yet is claimed to drill through hard granite at up to 26 ft per hr. One-cyl engine's floatless carburetor permits drilling in all positions from straight

down to 45° upward to a depth of 13 ft. Cobra can be converted from drill to breaker within seconds by changing three small parts. A BSM-42 Atlas Copco drill steel grinder, designed for field-mounting on the Cobra's packing case, is powered by a flexible shaft operating off the Cobra itself. **Circle No. 6.**

Taper-Socket Bits

Brunner & Lay Inc. announces a new line of taper-socket type Rok-Bits. Bits feature simple removal from drill rod and no body distortion on locking. Gauge sizes avail-

able for ⅞-in. drill steel are 1¼-in., 1⅜-in., and 1½-in. in #7 Class A Taper; and for 1-in. steels, 1⅝-in., 1¾-in. in #8 Class B Taper. Bronze shims are supplied with each bit. **Circle No. 7.**

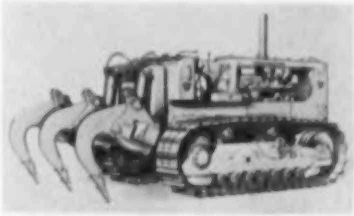
One-Door Bottom Dumper

Good balance results from a low center of gravity in this one-door bottom dumping mine car by *Sanford-Day Iron Works Inc.* Outside

frame construction permits maximum width door opening. No angles or stiffeners are used on top side of dumping door, and shedding is clean. Spring trucks and greater overall length can be provided. **Circle No. 8.**

Cat D9 Ripper

Mounted on the Cat D9 Tractor, a new ripper by *Caterpillar Tractor Co.* consists of two mounting brackets, hydraulic cylinders, beam assembly, and three teeth. Complete ripper weighs 10,830 lb. Teeth, which

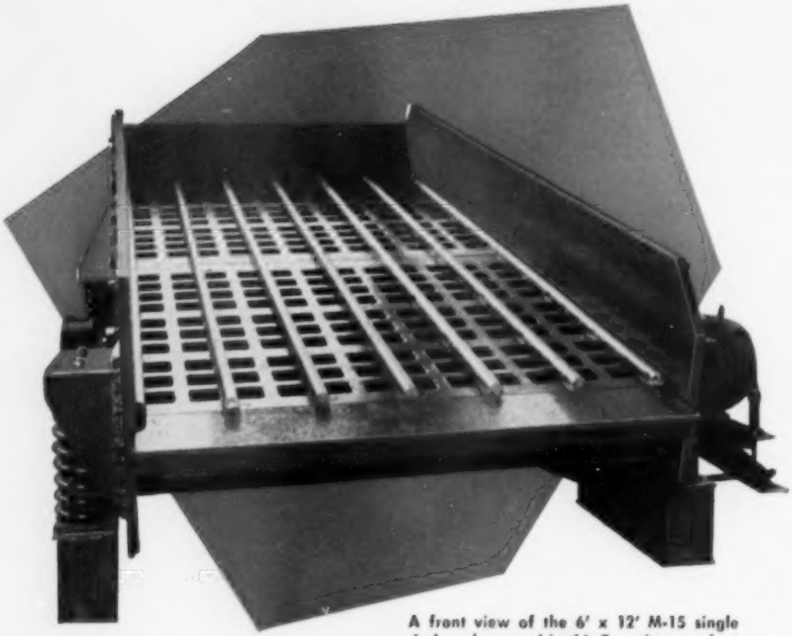


have replaceable hardened cast steel points, will swivel up to 10° to minimize rugged side thrusts. Used primarily for hard material break-up before scraper loading, the ripper may be used on frozen ground and stratified shale. **Circle No. 9.**

News & Notes

Wilmot Engineering Co. of White Haven, Pa., builders and equippers of coal preparation plants for almost 50 years, is undertaking an expansion program. One new building will more than double the facilities of their engineering department. The Wilmot-OCC Heavy Media Vessel is one coal preparation unit in a long-established line of mineral cleaning equipment.

430 long tons per hour of Taconite ore handled by this SIMPLICITY scalper



A front view of the 6' x 12' M-15 single deck scalper used in this Taconite ore plant as a primary and secondary scalping unit.

Lumps up to 24" of hard, tough, extremely abrasive Taconite ore are scalped by this Simplicity 6' x 12' Model M-15, at a throughput rate of 430 long tons an hour. This primary scalper is accompanied on the job by six other heavy duty Simplicity units, all of them, of course, handling the same gruelling fast flow of Taconite. First operation in the Taconite processing is feeding the ore to the primary scalper: this is done by a Simplicity 6' x 16' Model MA Feeder. Large chunks are fed off the 6' x 12' single deck M-15 primary scalper onto a Simplicity 6' x 20' Picking Table, where all obvious shale, stone, and other foreign material is removed. From here, the ore is put through a jaw crusher, and from the crusher two Simplicity 5' x 20' Feeders set in tandem deliver it to the secondary scalper. This unit, like the primary, is a Simplicity M-15 6' x 12' Heavy Duty Scalper. Fines from this operation now go to a Simplicity Double Deck 6' x 12' M-15 Scalper, where they are both scalped again and graded. Larger lumps are fed through a cone crusher, then they are likewise scalped and graded. The ore is now ready for extraction. This whole plant is set to work 24 hours a day seven days a week . . . and the rugged Simplicity equipment assures that down time will be negligible. Write today for details of Simplicity units for your own operation.

A Simplicity 6' x 12' M-15 Double Deck Scalper, used for both scalping and sizing in one operation.

100

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FOR EXPORT: BROWN AND SITES, 50 CHURCH ST., NEW YORK 7, N. Y.

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(21) DIESEL-POWERED TOWBOAT: *Dravo Corp.* has a RAM-class 70-ft diesel powered towboat to be used in medium and short-haul towing, sand and gravel operations, coal and oil transportation, barge shifting. The Dravo RAM is powered by two 290-hp Atlas diesels and features hydraulic steering, reverse reduction gears, forced-air heat, and inside passageways. Quarters are provided for a crew of eight.

(22) TRANSITE INSTALLATION: "How to Install *Johns-Manville* Transite Pressure Pipe for Overhead Industrial Water and Process Lines," is the title of a new 48-page guide. Diagrams and text cover such items as machining and cutting, expansion and contraction, testing, and typical systems. Ring-bound guide also lists suppliers of fittings, couplings, and accessories.

(23) MOLY IRON CASTINGS: First two bulletins of a series have been issued by *Climax Molybdenum Co.* on the use of molybdenum as an alloying element in gray iron castings. Major contribution of molybdenum is strength, but its properties of toughness, growth resistance, wear resistance are also needed in many of these castings.

(24) INDUSTRIAL HOSE: A condensed catalog listing hose, fittings, socketless kits, and self-sealing couplings has been released by *Aeroquip Corp.* Socketless fittings require only two steps in readying for use: lubrication of hose bore and fittings, and pushing the hose on the fittings.

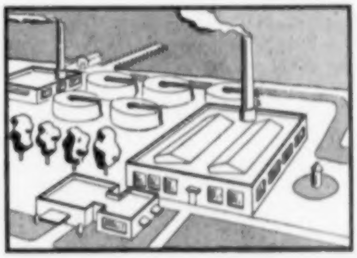
(25) DIESEL APPLICATIONS: Reference booklet from *Detroit Diesel Engine Div.* of General Motors Corp. lists over 1000 models of construction and industrial equipment available with Detroit Diesels as standard or optional power. Equipment ranging from small pumps to giant excavators and earthmoving vehicles use these engines that are available in models of from 30 to 893 hp.

Free Literature

(26) MILL EQUIPMENT: *Western Machinery Co.* has a 4-page folder that illustrates a line of equipment and services for mines, mills, and process plants. Laboratory testing services and engineering, design, and construction facilities are included with specifications of equipment for conditioning, classification, flotation, heavy media and gravity concentration.

(27) CENTRIFUGAL PUMPS: Class CRV cradle-mounted pumps by *Ingersoll-Rand* have capacities from 5 to 2800 gpm and pressures of 10 to 525 ft total head. Cross-sections, typical installations, dimensions, and performance tables are given in Form 7223-B which also covers various modifications available for special applications.

(28) PLANT ENGINEERING: Engineering, design, and construction on mines, mills, process plants is handled by W. K. E. Div. of *Western Machinery Co.* A 28-page folder illustrates some typical results of work which the company will handle in any phase from preliminary design to turn-key jobs.



(29) DIESEL ABC'S: "Answers to Questions About Diesels" is a fully illustrated booklet from *Cummins Engine Co. Inc.* designed to acquaint the reader with basic principles of diesel operation. Answers in the 24-page booklet are given in simple non-technical terms and cover such subjects as ignition, fuels and fuel economy, supercharging and turbocharging, application, power ratings.

(30) DRY-PROCESSING EQUIPMENT. Eight pages of "Sturtevant Dry Processing Equipment—the 'Open-Door' to Lower Operating Costs over More Years" are offered by *Sturtevant Mill Co.* "Open Door" is feature allowing easy accessibility to the vital parts of certain units for quick cleaning, inspection, and maintenance. Specifications are given of laboratory units as well as production equipment.

(31) DRAFTING PROCEDURE: Standard and simplified drafting practices are the topic of a 56-page booklet offered by *American Machine & Foundry Co.* Simplified method covered in the last 24 pages is intended as a supplement and not a replacement for standard drafting procedure.

(32) ALLOY STEEL TUBING: Tubular Products Div. of *The Babcock & Wilcox Co.* has technical data on tubing of the 4100 series steels. Carburizing, thermal treatments, critical points, mechanical properties, welding, and machining are detailed. Tubing is seamless and is produced in sizes up to 9⅝ in. OD in a wide range of wall thicknesses. It is furnished hot-finished, cold-drawn, or roto-rocked.

(33) STEEL FLOORING: A 12-page manual of specifications and installation methods for prolonging the life of industrial floors with Klemp Hexteel and Floorsteel is offered by *Klemp Metal Grating Corp.* These floor armors are designed for heavy duty and are claimed ideal for use as non-skid safety flooring.

MAIL THIS CARD

for more information on items described in Manufacturers News and for bulletins and catalogs listed in the Free Literature section.

9

Mining Engineering **29 West 39th St.** **New York 18, N. Y.**

Not good after Dec. 15, 1956—if mailed in U. S. or Canada.

Please send { More Information ☐ / Price Data ☐ / Free Literature ☐ } on items circled.

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Company______________________________

Street______________________________

City and Zone__________________State__________

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11	12	13	14	15	16	17	18	19	20
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41	42	43	44	45	46	47	48	49	50
51	52	53	54	55	56	57	58	59	60
61	62	63	64						

Students should write direct to manufacturer.

(34) LIST OF AMERICAN STANDARDS: An index and price list of 1600 American Standards are available in a 56-page booklet from the *American Standards Assn.* Special ASA publications, many of them free, are also described.

(35) DIESEL CRAWLER: *Allis-Chalmers Mfg. Co.* has a new 16-page catalog giving highlights of the 75-hp HD-11 diesel-powered crawler tractor. Major features and accessories of the medium-size unit are illustrated.

(36) WIRE ROPE ENDINGS: Four-page folder DH-531 from *American Chain & Cable Co.* covers Dualoc wire rope endings which are said to maintain full wire rope strength. Endings are offered with thimble or loop and are anchored under steel collars.

(37) STEEL BUILDINGS: A new bulletin from *Armco Drainage & Metal Products Inc.* shows the advantages of steel-paneled buildings. Features reported are: low cost, ease of erection, neat appearance, convenience of buying, and standard size for every floor space requirement.

(38) DUSTFOE RESPIRATOR: Bulletin 1004-2 from *Mine Safety Appliances Co.* gives data on the new Dustfoe Ultra-Filter Respirator. Six-oz unit has an aluminum facepiece that gives comfort while a Type H cartridge protects the wearer against minute particles, including dust and airborne organisms. Filters can be slipped in or out easily for changing or cleaning the respirator.

(39) SWINGING DRAWBAR: Designed to make the No. 955 Traxcavator more versatile, a new swinging drawbar attachment has been developed by *Caterpillar Tractor Co.* which can be used to pull the No. 40 Scraper or other towed equipment. Drawbar has wide lateral movement and can be locked in several positions.

(40) KOROSEAL INSTALLATION: *B. F. Goodrich Co.* offers an 8-page installation bulletin on its rigid thermoplastic pipe, Koroseal. Applications are reviewed and installation procedures include pointers on fittings and valves.

(41) DATA CHART: An engineering data wall chart that gives tables on decimal equivalents, temperature conversion, wire size and current ratings, mechanical and electrical conversion tables is offered by *Perkin Engineering Corp.*

(42) WINDSTORM DAMAGE PREVENTION: By attention to even minor details of design and construction when erecting new buildings or making repairs to old ones, much can be done to reduce windstorm damage losses according to the *National Board of Fire Underwriters.* The organization has just issued a 40-page technical booklet on the subject for use by engineers and others concerned with building standards. Recommendations are given for predisaster planning, safeguarding water supply, and fire prevention and control.

(43) GAS TURBINE: The Mark TA 1130-bhp gas turbine for industrial, refining, and processing applications is available from *Clark Bros. Co.* Said to be one-third as heavy as other prime movers of comparable horsepower, the turbine is suited to portable pumping or generating uses. Exhaust gas temperature is high enough to make waste heat recovery economical and large quantities of steam can be generated.

(44) DENSITY TESTING: *Soiltest Inc.* has the Volumeasure CN-980 which provides a method for determining the in-place density of soils and construction fill materials. Instrument consists of a graduated cylinder, aluminum guard, rubber balloon, pressure-vacuum actuator bulb, guard base, and a field density plate. Design permits easy assembly and disassembly.

(45) MILL FEED CONTROL: "Electric Ear" is an electronic grinding mill feed control by *Hardinge Co. Inc.* which automatically regulates the flow of feed material, wet or dry, to a continuous or pulverizing mill, based upon the grinding sound level. Human factor is eliminated and constant mill loading is maintained regardless of variations in the feed. Overloading is also prevented, and mill efficiency is claimed increased 10 to 20 pct. Bulletin 42-A gives operating principles, applications, and illustrates typical installations.

(46) AIR LOCOMOTIVE: Model 401 air locomotive by *Eimco Corp.* provides low-cost underground transportation with freedom from fire and explosion hazards. Using an air motor, the unit can pull an 18 to 20-ton train load and its pressure vessel can be charged anywhere on a mine air system. Two speeds forward and two in reverse are featured and a neutral position allows economical free wheeling.

(47) SELF-LOCKING FASTENERS: Catalog 11B from *Nylok Corp.* details the line of Nylok one-piece self-locking fasteners. Locking is provided by a tough nylon plug imbedded permanently in the threaded section. Applied to either male or female section, the plug makes positive joint which is claimed not to jar loose from shock or vibration. Applications for special-purpose fasteners are also given.

(48) DUST BUCKET: *Mine Safety Appliances Co.* has a new device for easy inexpensive dust collection in overhead rotary drilling operations where flute augers are used. The unit consists of a rubber hood and a collecting bucket with a support assembly, all of which slide over the drill. The bucket does not interfere with normal operations whether drilling is done vertically or diagonally overhead.

(49) JAW CRUSHERS: Overhead eccentric Jawmaster crushers from *McLanahan & Stone Corp.* feature force-feed action and long-jaw design. Thirteen sizes are produced, ranging from 10 in. x 16 in. to 40 in. x 48 in. Capacities up to 750 tph are offered.

(50) COPPER FLOTATION: A flotation flowsheet study on the treatment of copper as chalcopyrite with gold and silver values is available from *Denver Eqpt. Co.*

(51) MANHOLE FITTINGS: Manhole and handhole fittings for tanks and pressure vessels are described in a new bulletin from Claymont Steel Products Dept. of *The Colorado Fuel & Iron Corp.* Available in a wide variety of sizes, shapes, and specifications, the fittings meet Underwriters Laboratory requirements for use on storage tanks containing hazardous liquids, either above or under ground.

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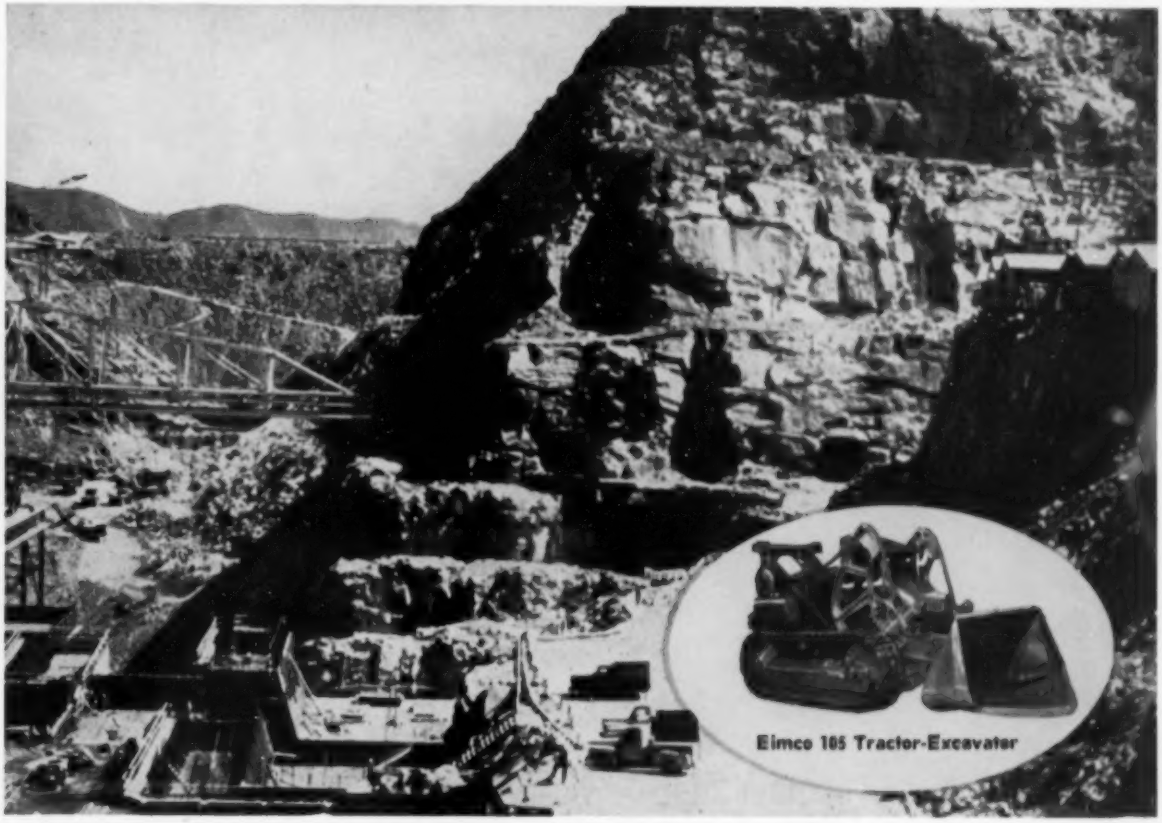


Eimco 105 Tractor-Excavator

INDIA – EIMCO 105's KEEP GRUELLING SCHEDULE

Two Eimco 105 Tractor-Excavators have each worked 8,000 hours in 12 months to keep progress on schedule at a huge dam project in India.

The machines have received intelligent maintenance and repairs have been small.

Eimco 105 Tractor-Dozer

At work on diversion, penstock and highway tunnels, trained Indian crews operating the 105's are doing an excellent job of tunnel driving. In some instances, advance for the size of tunnel being excavated may establish new world records.

"Eimco 105's are preferred equipment to use for tunnels of this type," says one official of a contracting firm. "The transmission, clutches and drive on both machines have not been touched in 8,000 hours of operation. They are in good condition and we expect them to last many more years."

Have you considered why the Eimco 105 is "preferred equipment" to contractors of huge dam, tunnel and road projects in the export market?

It's becauuse their dependability is reflected through their engineered strength to stay on the job around the clock – day in and day out.

The Eimco 105's dependability eliminates the necessity of a sizeable parts depot. Eimco's are built to 100,000 hour standards for service in remote areas. Time saved by Eimco's working continuously with no down time for repairs is a big factor in selecting equipment.

Conditions being equal, Eimco 105's will produce more at less cost and in less time than comparative equipment. Let Eimco show you how this versatile unit can out-perform and out-work heavier, more expensive units.

See the Eimco 105 before you buy any crawler tractor equipment.

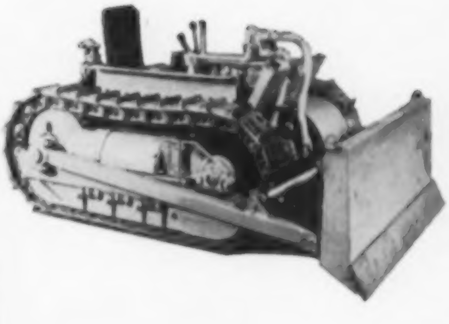
THE EIMCO CORPORATION

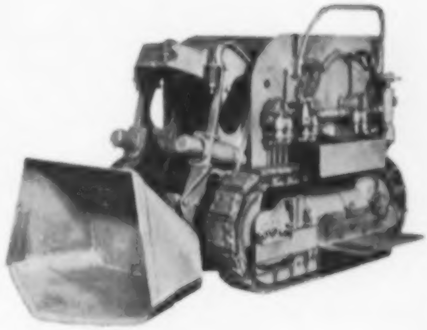
Salt Lake City, Utah—U.S.A. • Export Offices: Eimco Bldg., 52 South St., New York City

New York, N. Y. Chicago, Ill. San Francisco, Calif. El Paso, Tex. Birmingham, Ala. Duluth, Minn. Kellogg, Ida. Baltimore, Md. Pittsburgh, Pa. Seattle, Wash. Cleveland, Ohio Houston, Texas Vancouver, B. C. London, England Gateshead, England Paris, France Milan, Italy Johannesburg, South Africa

B-236

NOW! IN CRAWLER TYPE MACHINES FOR TRACKLESS WORK, THE SAME HEAVY RUGGED CONSTRUCTION AND DEPENDABILITY THAT THE INDUSTRY HAS HAD IN EIMCO WHEEL TYPE MACHINES.





Fast, sharp maneuvers, regulated by fingertip control make the EIMCO 630 EXCAVATOR a production giant and an operator's delight.

With the power at his fingertips to move one track into forward motion while the other is in reverse motion, an operator can make the 630 veritably "walk" around a muck pile—working from any angle without backing to make a new approach.

Eimco 630 agility permits operators to quickly master movement of the machine to a point that lost motion is eliminated between excavating and discharge stages.

While the 630 is moving between points of excavation and dumping, the bucket progressively elevates in an arc. Through proper timing, arrival of the 630 and bucket discharge become simultaneous operations. And the large half-yard bucket provides greater tonnage at every discharge.

These three pluses—extra maneuverability, operational ease and larger bucket capacity added in terms of economic value to you mean **MORE TONNAGE IN LESS TIME.**

THE EIMCO CORPORATION

Salt Lake City, Utah—U.S.A. • Export Offices: Eimco Bldg., 52 South St., New York City

New York, N. Y. Chicago, Ill. San Francisco, Calif. El Paso, Tex. Birmingham, Ala. Duluth, Minn. Kellogg, Ida. Baltimore, Md. Pittsburgh, Pa. Seattle, Wash. Pasadena, Calif. Houston, Texas Vancouver, B. C. London, England Gateshead, England Paris, France Milan, Italy Johannesburg, South Africa

B-215

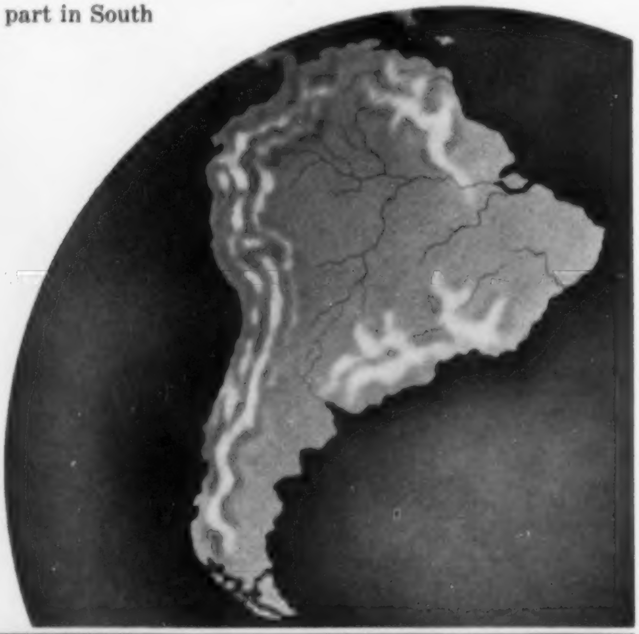
Ready for the long trip to South America via overland highway to the Port of Houston where they will be placed aboard ship to South America.

seventy-five DARTS for South America

Sixty-nine 25-ton trucks and six 10-ton trucks ... believed to be the largest off-highway truck order ever placed. The 25-ton trucks, three of which are shown here ready for delivery, are powered by 335 H.P. turbo-diesel engines. They are the standard model 25-SL DART TRUCKS with Fuller transmissions and Twin-Disc converters for downhill braking .... the trucks will be operating at high altitudes ... 9,000 to 12,000 feet!

DART is proud to play such an important part in South America's mining program.

DART'S "Jr. Workhorse" ... Model 10SL, 10-tonner with 165 H.P. turbo-diesel and double reduction rear axle. Tires are 12:00 x 24 all around and steering is hydraulic. Six of these are included in the South American program.



DART TRUCKS
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SUBSIDIARY OF THE CARLISLE CORPORATION

D-120

See us at the American Mining Congress—BOOTHS 817-825

Private Uranium Feed Plant Proposed

Kennecott Copper Corp. and Koppers Co., Inc. will submit a joint proposal to the AEC on October 1 to design, construct, and operate a feed materials processing plant with an annual capacity of up to 5000 tons of uranium salts for AEC purchase.

Canadian Production to Reach New Level

Canada's Federal Minister of Mines has announced that mineral production this year would reach $2 billion.

"Operation Overthrust" Launched

Mining interests in the U. S. and Canada have begun a cooperative mining survey which will cover an area of 357,000 sq miles. Aerial photos will be used in conjunction with geological data in the study extending over the Pre-Cambrian Shield of Canada and southward into Michigan and Minnesota.

Possible Major Zinc Deposit in Brazil

A survey in Brazil has disclosed a deposit in northwest Minas Gerais with ore samples reported averaging 35 pct zinc. Mineralized faults occur over a range of about 6 miles and also contain copper. Almost all zinc and copper used in Brazil is imported at present.

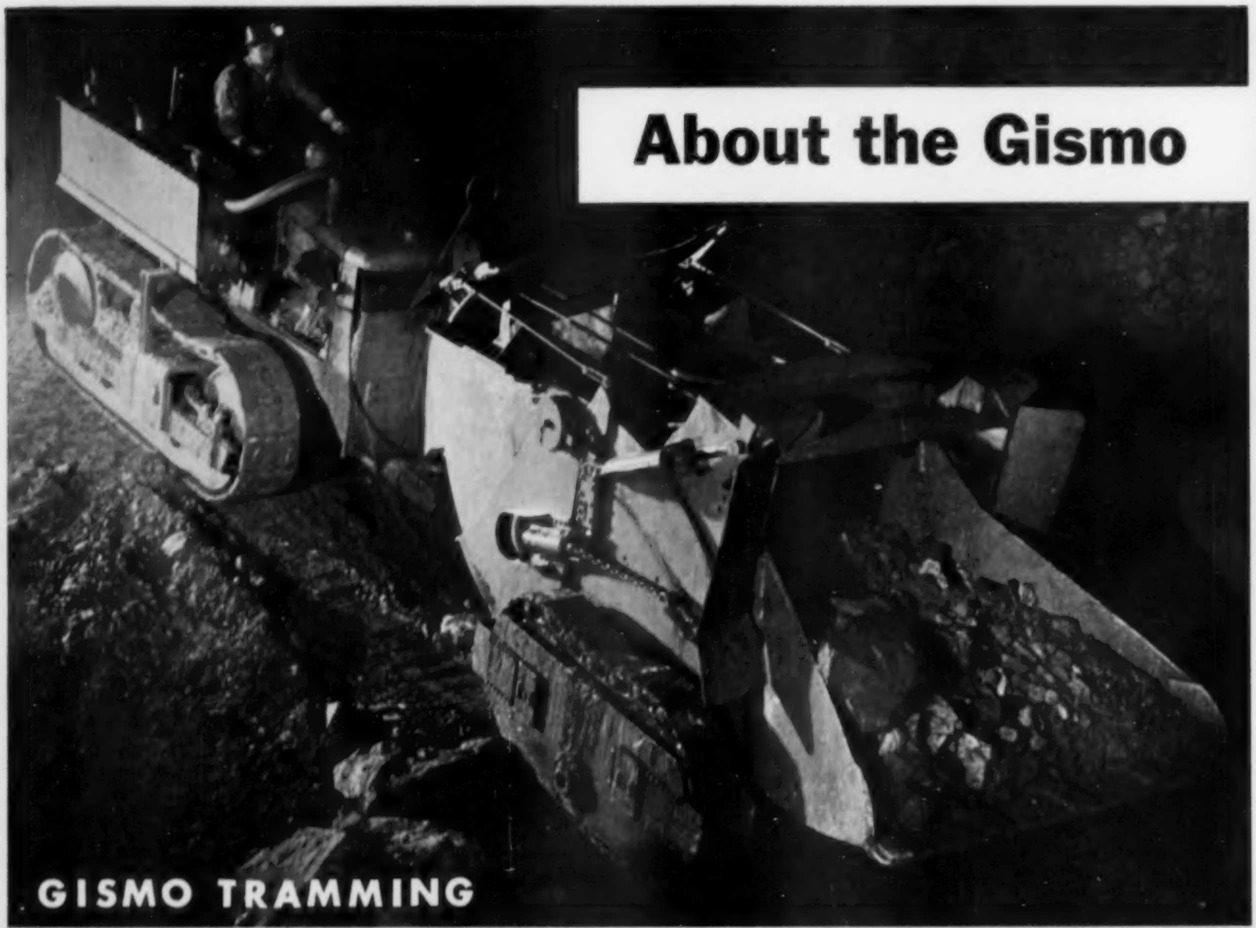
Australia Reports New Bauxite Findings

Large bauxite deposits on the west coast of Cape York peninsula in Northern Australia have been announced by Consolidated Zinc. Corp. Ltd. A subsidiary of the firm is expected to work the area when ore quality is proved.

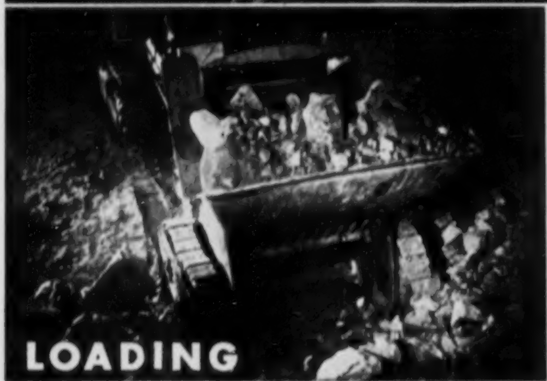
AEC Modifies Uranium Circular 5, Revised

Sellers desiring to deliver more than 1000 short tons of uranium ore during any calendar year need no longer submit proof that funds received as development allowance have been spent for development or exploration during the contract period or within six months thereafter.

About the Gismo



GISMO TRAMMING



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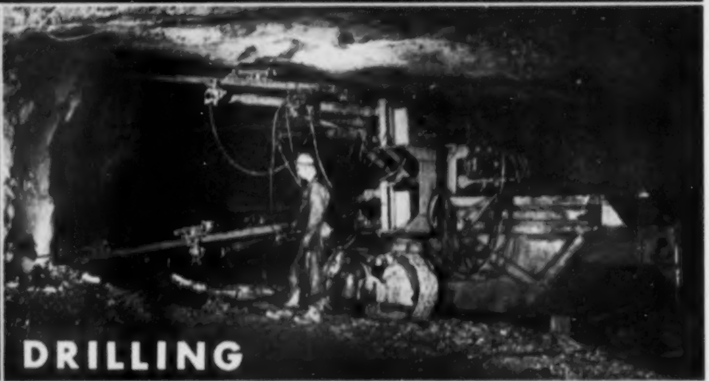


DRILLING

DUMPING / IN PRODUCTION

DUMPING / IN S-D CARS IN DEVELOPMENT

ORES RESEARCH BUILDING DEDICATED

New Ores Research Building at Michigan Tech will serve as headquarters of the college's Bureau of Mineral Research. It is Michigan's first state-supported mineral research laboratory.

August 8 marked the dedication of the new Ores Research Building at the Michigan College of Mining and Technology, Houghton, Mich. The new building will serve as headquarters for the college's Bureau of Mineral Research, and is Michigan's first full-fledged state-supported mineral research laboratory.

Grover J. Holt, President-Elect of AIME, delivered the dedication address. Mr. Holt emphasized the importance research has had in the development of the American economy. He received the honorary degree of Doctor of Engineering from Michigan Tech at the ceremonies.

Dr. Grover C. Dillman, president of Michigan Tech, and M. E. Volin, director of the college's Bureau of Mineral Research, also spoke. Some 500 persons representing the minerals industries, government, and education attended the dedication.

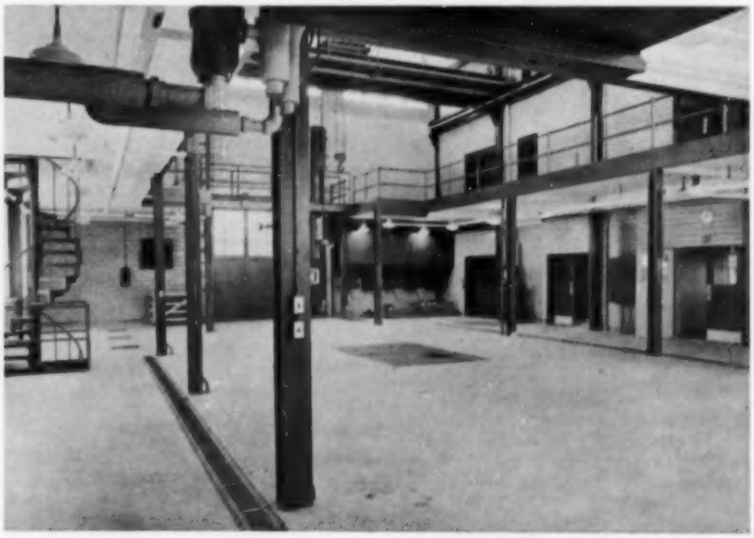
Mr. Volin, pointing up the research problems confronting Michigan's mineral industries, said that the Bureau will be prepared to consider a wide range of problems. However, the most immediate will be in the processing of low-grade iron and copper-bearing formations. He summarized these problems as follows:

"One of the most pressing problems is to supply increasing tonnages of merchantable ore to the iron and steel industries. Michigan's iron ores come largely from underground operations which characteristically are more costly and less flexible for mechanization than surface operations. Costs have increased as shipping ores have become less accessible. At the same time competition from premium grade imported ores and beneficiated products has grown.

"It has been conservatively estimated that Iron, Dickinson, Gogebic, and Marquette Counties have hundreds of millions of tons of iron formations containing 25 pct or more iron. If the problems of utilizing these low grade reserves of partially leached and metamorphosed oxides and carbonates can be solved, it is estimated that 750 million tons of concentrates containing as much iron as Michigan has produced to date will be available as merchantable products. As this estimate includes only the upper part of the formation to a depth of 100 ft below ledge, much of this potential ore is accessible for surface mining. Some important new developments based on the extensive low grade resources have resulted from ore beneficiation research, but increasing efforts are needed if Michigan is to maintain a strong iron mining position. The other mineral resources have problems of similar magnitude although different in character.

"A full-scale attack on the mineral problems will involve research on geophysical techniques, mining methods, mineral dressing processes, and even into the metallurgy of smelting, refining and other processing of the metals and non-metallic minerals. The development of better geophysical methods is essential in Michigan where the ore formations are largely covered. Applications of new scientific information to both underground and surface mining problems are needed to increase mechanization and ore output. Both basic and applied research must be focused on the problems of beneficiating the ores and converting the raw products into manufactured goods.

"The general objectives of the Bureau of Mineral Research are to study and develop processes and techniques for utilizing Michigan's mineral resources that are not now considered economic, for finding new resources, and for enlarging the uses of the mineral products. It also serves the objectives of education in



Pilot plant of Michigan Tech's research building has more than 10,000 sq ft area.

the mineral industries. A balanced program of applied and basic research is being focused on the problems. Applied research aims to improve existing processes and techniques, and basic research will apply new scientific information to the problems for the development of ideas that may lead to discoveries of new processes and techniques.

"The program immediately visualized will be largely in the fields of mineral dressing and chemical processes at both laboratory and small pilot plant levels. Later, the activities will be enlarged to include pyrometallurgical investigations. A geophysical laboratory has been active for several months in cooperation with the Physics Dept. Mining research will be an added area of study in the future.

"The program has the advantage of assistance given by a research committee made up of selected staff members of the college. This committee advises on methods for approaching problems and designing experiments, criticizes scientific procedures and application of theory, reviews results of experiments, and brings attention to new ideas and scientific knowledge that may be applied to the mineral problems.

"The program is also to receive guidance from an industrial committee which will meet at least once a year to review the work accomplished, discuss the mineral problems and advise on such things as policies of cooperation with industry and the needs for work in specific lines.

"Graduate and undergraduate students in the minerals fields are given work in the research program to the extent that such part-time workers can be used. A number of fellowships are offered on mineral problems; these lead to advanced degrees in metallurgical engineering, mineral dressing, and geophysics and are administered jointly by the departments offering these degrees. This type of cooperation assists the objectives of education and provides the mineral industries with highly trained graduates.

"The program provides a service to the mineral industries and governmental agencies, on a sponsored basis, on minerals problems of specific interest to the sponsor. This service includes all lines of minerals research and testing by standard or special mineral dressing procedures. A proposal showing the basis for costs of this non-profit service will be furnished on request."

Building and Equipment

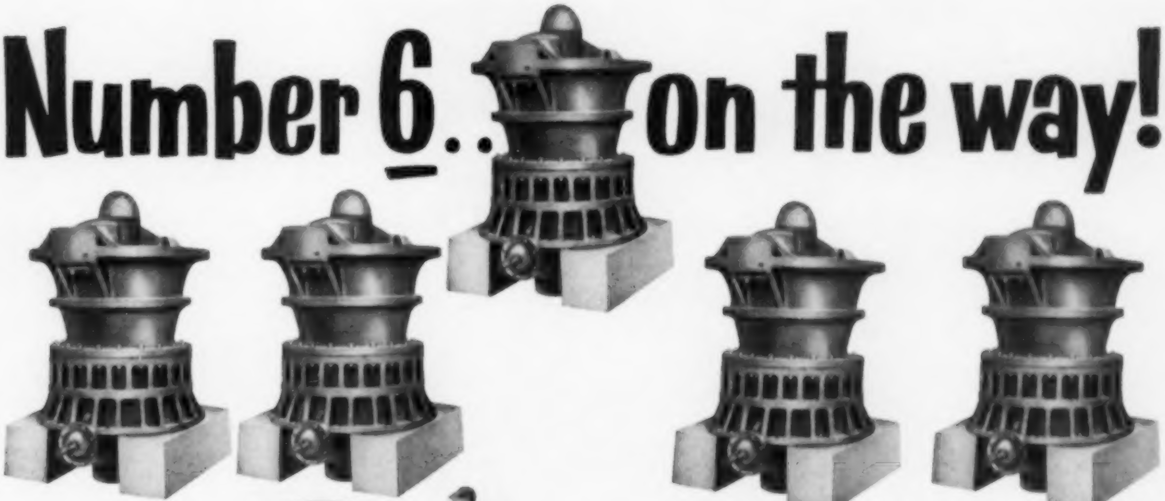
Built and equipped at a cost of $750,000, the Michigan Tech Ores Research Building is based on a concept that research is dynamic, that objectives and methods of reaching them may change, and that the facilities must have versatility for modification to meet changing conditions.

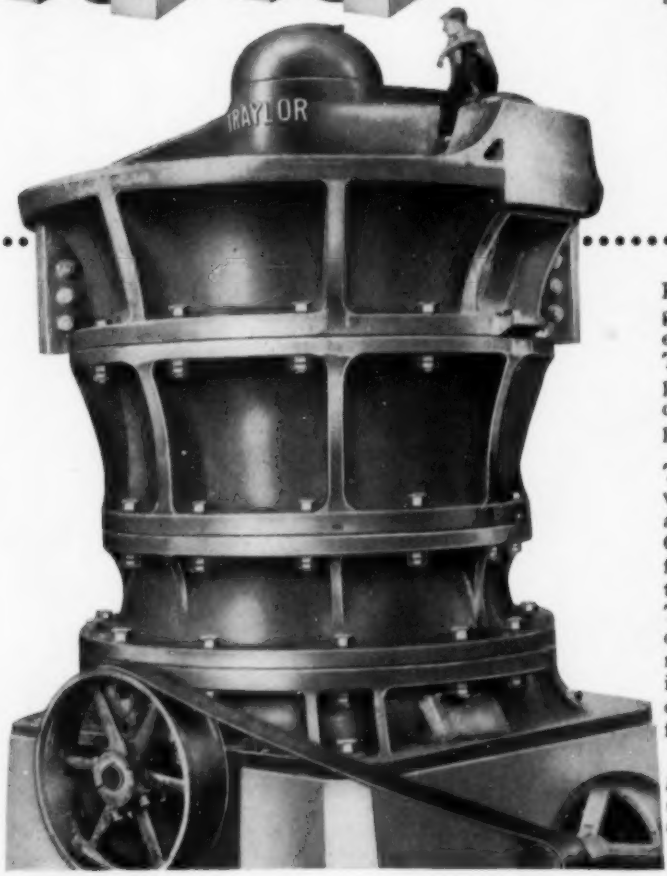
The laboratory-office section is 132 ft long by 55 ft wide, and encloses 283,000 cu ft on two floors and a basement. It is of modular design, the basic unit being 20 ft long by 12 ft wide. Each unit includes two removable panels for access to conduits and piping carrying the various utilities up from the service tunnel; these services include 110-v and 440-v electric power, high and low pressure steam, hot and cold water, gas lines, compressed air, and Duriron drains. Walls between the laboratories are non-load bearing and the steel partitions can be removed to enlarge the modules as desired. This design provides for expansion without modifying permanent walls and floors and also is arranged for systematic additions to the building.

All of the offices and laboratories open into a central corridor on each floor. The seven offices, reception room, conference room and entrance vestibule cover 2500 sq ft of floor area. The 17 laboratories and machine shop occupy 7000 sq ft. Remaining space is taken up by the central corridors, service tunnel, general storage, shower-locker rooms, stairs, electrical and steam control rooms, elevator well and the penthouse for exhaust fans and ducts. All rooms and corridors

(Continued on page 888)

Number 6... on the way!





Another Traylor TC Gyratory is added to the 5 on order for Big Taconite Project

Profitable production of iron ore from low-grade Taconite calls for the most modern, efficient methods and equipment. That's why Traylor Gyratories were the choice for both primary *and* secondary reduction at one of the extremely hard Taconite-bearing ore properties.

The initial order included a Gyratory Crusher with 60″ receiving opening and 102″ diameter crushing head, this huge TC Primary Crusher takes chunks of ore the size of a flat-top desk and reduces them to 12″ at the rate of 4,000 long tons an hour. Four Traylor 36″ Gyratories were included on the original order . . . to take the 12″ ore and reduce it to minus 5″ in the secondary crushing operation. Now . . . we've received an order for another 36″ Gyratory to join the five now being built.

For complete specifications and description of the outstanding features of Traylor TC Gyratory Crushers, send for your copy of Traylor Bulletin #126.

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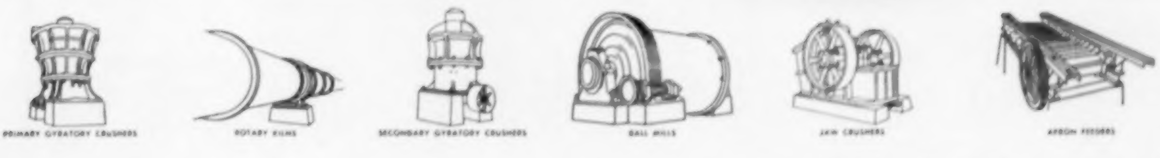

IN SOUTH AFRICA

AROUND THE CLOCK

A TANK CAR AN HOUR OF H_2SO_4

This FluoSolids System at West Rand Consolidated Gold Mines, Ltd. on South Africa's fabulous Witwatersrand was started up early in 1952. The first of several to go into operation on the Rand, it was also the first in the world to combine FluoSolids roasting of pyrite with a contact acid plant.

Over 1650 tons of H_2SO_4 — enough to fill twenty-four tank cars — are being produced every day for uranium leaching at seven South African mills.

An important part of each of these installations is a Dorrco FluoSolids System. Cumulatively the Systems include nineteen Reactors, of which sixteen were on original order and three on repeat orders, plus additional Dorr-Oliver and auxiliary equipment to produce a high strength SO_2 gas for acid manufacture by conventional contact acid plants.

Total feed to the Systems is 1450 tons per day of pyritic gold mill tailings — averaging 35 to 45% total sulfur, gas production is 75,000 to 82,000 SCFM. Gas strength averages 12 to 13% SO_2 . . . sulfur recovery approximately 90%.

The efficiency and economics of the Dorrco FluoSolids System is in evidence in these facts. Additional representative proof that the FluoSolids process can produce an SO_2 gas at lower investment and operating costs than other roasters.

If there's a step in your flowsheet where intimate contact between solids and gases is essential, fluidization should be investigated. Just drop a line to Dorr-Oliver Incorporated, Stamford, Connecticut.

FluoSolids is a Trade Mark of Dorr-Oliver Incorporated, Reg. U. S. Pat. Off.

DORR-OLIVER
INCORPORATED
WORLD-WIDE RESEARCH • ENGINEERING • EQUIPMENT
STAMFORD • CONNECTICUT • U. S. A.

500 LARGEST

LISTINGS of the great industrial corporations are in constant change as mergers are made or the discovery of new processes causes a medium-sized firm to vault, by sales increases, to a spot far above its competitors. But even though the mighty industries are never assured a stationary position in the ranks, a certain number manage to hold a high place in the long line. Checking through the second annual edition of the *Fortune* directory of the 500 largest U. S. industrial companies we were not surprised to find a large number of mining names. From top firm down, these nonferrous mining names are among the 500 industrial greats and are listed here approximately according to size: Union Carbide & Carbon, Aluminum Co. of America, American Metal, Anaconda Co., Olin Mathieson Chemical Co., Kennecott Copper, American Smelting & Refining, National Lead, Reynolds Metals, Phelps Dodge, Johns-Manville, Minnesota Mining & Mfg., Kaiser Aluminum & Chemical, U. S. Gypsum, Revere Copper & Brass, Pittsburgh Consolidated Coal, National Gypsum, St. Joseph Lead, Eagle-Picher, International Minerals & Chemical, Pocahontas Fuel, Texas Gulf Sulphur, Ruberoid, Harbison-Walker Refractories, Island Creek Coal, American Zinc, Lead, & Smelting, Cerro de Pasco, Lehigh Portland Cement, Ideal Cement, Calumet & Hecla, Freeport Sulphur, Columbian Carbon, Climax Molybdenum, Consolidated Coppermines, Vanadium Corp.

Steel and iron names also make up a good portion of the top 500 companies. From largest on down they are: U. S. Steel, Bethlehem Steel, Republic Steel, Jones & Laughlin Steel, Armco Steel, Inland Steel, National Steel Corp., Colorado Fuel & Iron, Allegheny Ludlum Steel, Wheeling Steel, Crucible Steel, Pittsburgh Steel Co., Sharon Steel, McLouth Steel, Kaiser Steel, Granite City Steel, Cleveland-Cliffs Iron, Acme Steel, Detroit Steel Corp., Keystone Steel & Wire, Interlake Iron, Lukens Steel, Copperweld Steel, Barium Steel, Ceco Steel Products, Wood (Alan) Steel, Laclede Steel.

PATENTS

IT does not take a great deal of knowledge of patent law to appreciate the significance of a recent decision by the U. S. Court of Customs and Patent Appeals. This decision—of particular interest to editors, to technical authors and to potential authors of technical articles—in essence says that the date of receipt of an article printed in a publication can no longer be used by the patent office as a bar to an inventor desiring a patent. That this upsets a precedent of long standing also goes without saying.

In the past the notation appearing in a box, or appended to an article in a technical magazine "Manuscript received April 15, 1972" was taken as prima facie evidence that the invention was *known*. In this connotation the word *known* has a particular significance, i.e. that it is known to persons "versed in the arts", and hence that such publication if prior to patent date application constitute a bar to patenting the idea or invention.

In a recent case (*in re Emil Schittler et al., June 21, 1956*) the court ruled that "Placing the article in the hands of the publisher did not constitute either prima facie or conclusive evidence of knowledge or use by others in this Country of the invention disclosed in the article, within the meaning of the (statute)".

In arriving at this precedent-upsetting decision the court had access to the views of three patent law associations—The American Patent Law Assn., The Connecticut Patent Law Assn., and The New York Patent Law Assn.—all three of whom filed briefs as friends of the court. Incidentally all three also urged reversal of the then standing patent law office policy of reliance on the received date as determining the date on which an invention was widely known. It does not take a great deal of knowledge of patent law to see the implications in this decision, particularly those beneficial to potential technical authors and those assisting editors in getting articles they are interested in. On the other hand, a published comment has so far failed to suggest a further implication in this decision, and one which we will take the liberty here of pointing out. Without professing a knowledge of patent law, it seems likely that this particular decision can be turned and used in other ways.

Specifically, the case involved an author who had published an article and who also was the party applying for the patent. The problem arose because the date his manuscript had been received was prior to the effective filing date of his application at the patent office. Following its precedents the patent office therefore ruled that his invention was known prior to date of patent application and the application was therefore barred. In the light of this sequence of events, one wonders if in the future an author will be able to point to the date of receipt of his manuscript in attempting to counter a patent application dated a later date by someone else? This will no doubt be something for the patent law experts to resolve.

BECAUSE of its importance as a route for oil from the Middle East, the Suez Canal has been the cause for much concern since Premier Nasser of Egypt dictated the nationalization of the Universal Suez Canal Co. Concern with the oil market is more than reasonable since tankers made up about 65 pct of the millions of tons of shipping which passed through the canal in 1955.

But the canal is also of high importance in the transportation of Malayan and Indonesian tin, Indian manganese ore, Australian lead, zinc, and zinc concentrates, and other minerals from the east. Tonnages of metals and ores which passed from south to

north through the canal during 1955 are shown in the following table:

	Long Tons
Iron ore	*2,044,000*
Manganese ore	*1,687,000*
Zinc and zinc ore	*326,000*
Titanium ore	*286,000*
Chrome ore	*252,000*
Lead and lead ore	*161,000*
Copper and copper ore	*124,000*
Tin and tin ore	*104,000*
Aluminum and aluminum ore	*83,000*
Others	*233,000*
Total	*5,300,000*

Manganese is the item of main interest to the U. S. Of the 1955 shipments listed, the U. S. received 833,000 tons. The Office of Defense Mobilization employs the policy of excluding foreign supplies in planning long-term stockpile objectives, but unless a solution to the canal crisis is soon reached our short-term manganese supply will probably be affected, at least on a cost basis.

◆◆◆◆◆◆

ONCE upon a time, *efficiency expert* was a bugaboo name for a bright seemingly pleasant fellow who came into your office and, smiling benevolently, tried to prove that they didn't need good old Joe Smedly after all. The notion that the expert would bring changes that would be only hazily valuable and most definitely disagreeable probably kept a number of firms from hiring consultants for work that was sorely needed.

Actually the attitude of the top-notch industrial and business consultant today is to take a personal concern in the welfare of the company that hires him. After he has convinced his client that his business will find tonic in an outside-view evaluation of its various departments the consultant will launch his study. Later he'll present his ideas, not with a well-sharpened axe, but with a bundle of solid, well-considered advice.

Consulting is becoming big business, and it is good business. Some idea of the thorough techniques of the industrial consultant is gained by reading a new publication by C. C. Crawford for the Industrial Dept. of the Los Angeles Chamber of Commerce. The book, *Professional Consultant's Operations and Techniques*, is a report on suggestions from a number of consultants concerning problems met and solutions they see needed in doing their work. Interestingly, but not strangely, a suggestion is made that a consultant identify himself emotionally with the client. One who has tried it reports that the only way he can detach himself from his adopted problems is with a dose of sleeping pills.

The purpose and attitude of the consultant is seen in one section of the report which suggests: "Establish a permissive atmosphere as a groundwork for easy confidence, and as a means of encouraging group thinking. You can cut down lost motion greatly if you establish a personal relationship that allows everyone to tell you his thoughts freely and fully. As a consultant you are going to be used as a communication go-between and as an organizer of various and divergent views. Management cannot always get free and frank expression from the captive technicians, yet management and the technicians want full communication. You are the instrument of getting it. People are human, and it isn't logical to expect them to bite the hand that feeds them, nor to critize openly policies under which they have to operate but which they know to be questionable or feel to be wrong. You can obtain honest answers from confidential interviews if you open the channels of communication, gain frank responses, let people have their own ideas and express them freely, and don't obstruct their thinking or monopolize wisdom."

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UNDER strict scientific scrutiny, how good are today's basic tools for analyzing the current and future course of business?

National income, business cycles, economic growth, and other basic economic problems have been objects of study for 36 years at the National Bureau of Economic Research, a non-profit organization. The bureau's annual report indicates a heartening progress and serious lacks.

Director of Research S. Fabricant reports that gains in current information have been immense. Take for example the annual rates of family income and expense, of borrowing and expense. He points out that as recently as the early 1930's no figures were available on a current basis. Now the story can be read from quarter to quarter—even month to month.

But there is great difficulty in determining economic interrelationships even though we have much improved information about individual processes. Factors which arise outside of business life, such as the decisions of government, must be accounted for in any predictions—and they make the task a large one.

Wide notice, Mr. Fabricant remarks, has been taken of the fact that the debt of public agencies, consumers, and business increased $45 billion during 1955, although during the 1920's it did not increase more than $20 billion in any one year. Between the end of 1949 and the end of 1955 the debt total rose by $200 billion, more than the entire debt outstanding in 1929.

These figures alone are not alarming, he comments, because gross national product has risen more than debt since 1923, or since 1929, or since 1949; and "debt and economic growth seem to go together."

Questions of soundness in finance are not answered, however, by weighing growth of debt against growth of national output. Meaning of debt movements also requires knowledge of changes in structure of the financial system, and in this, current information is incomplete and much basic analysis is still to be done.

"Whatever we can learn about the operations of our economy," concludes Mr. Fabricant, "will help us resist hasty solutions and prepare us to build sound ones." At stake is "nothing less than the shape of our political as well as our economic future."

(Continued from page 882)
are lighted by fluorescent fixtures, heated by wall convectors, and conditioned by an air circulation system. Offices and corridors have acoustical ceilings. Laboratories are equipped with separate hood and exhaust systems for controlling fumes and dust.

The pilot plant is 82 ft long by 50 ft wide, and encloses 140,000 cu ft of working space on the main and basement floors and a perimeter balcony. This provides 10,700 sq ft of floor area. The coarse-crushing room in the basement is 30 ft long by 15½ ft wide. Some of the chief features of the pilot plant are a large entrance with mechanical lift door for admitting loaded trucks, a 5-ton overhead crane, a 5000-lb floor scale, a service elevator, floor drains and launders, Rotoclone air scrubber-exhausters, unit heaters, and ten steel bins for sample storage.

Several of the laboratory sections are equipped for specific functions. The chemical laboratory, along with weighing rooms and storage, occupies a triple module. An adjoining module is reserved for X-ray, spectrographic, and other such equipment. Occupying double sections are the flotation, magnetic, gravity, microscopy-photography, and sample preparation laboratories. A single module adjoining the flotation lab is equipped for sizing operations, including microsizing. Geophysical research is carried on in a single section. Units are reserved for pyrometallurgy, hydrometallurgy and other lines of research yet to be developed. The machine shop, along with tool and maintenance storage, occupies four modules opening onto the pilot plant as well as the main corridor. The shop is equipped to make special apparatus, equipment repairs, and to provide for the maintenance of the building. The conference room occupies two units and has space for a small library.

AEC Changes Map Releases

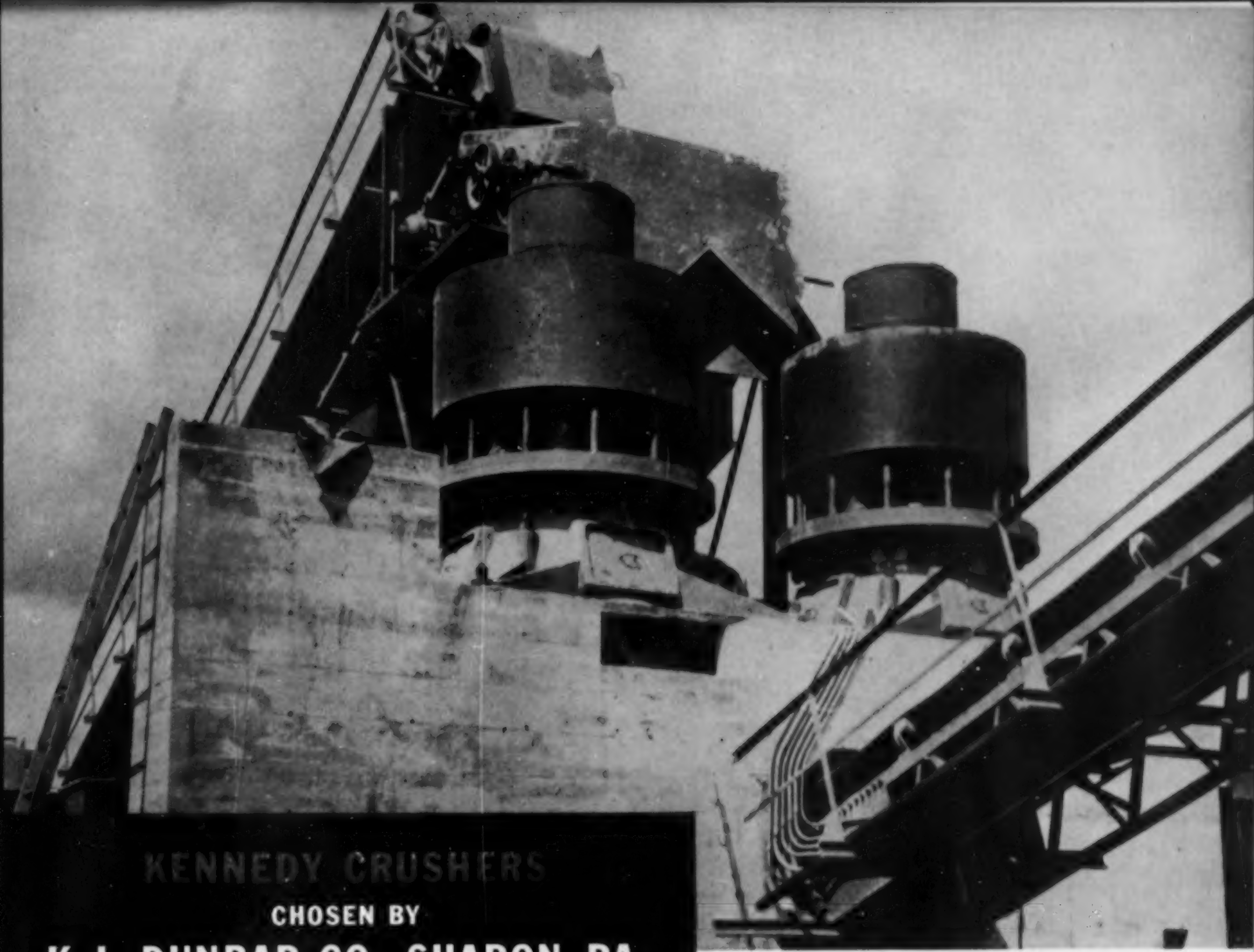
The Atomic Energy Commission has announced revised procedures for the public release of information concerning surface areas of high radioactivity located by government airborne reconnaissance.

Results of past surveys were made available by posting index maps showing anomalies on the 15th day of each month at specified locations; but under the new procedures, information concerning the location of anomalies in an area will be released only upon completion of the flying activities in the area involved.

Because there has been a great increase in the number of private airborne radiometric surveys, the commission's exploration program uses airplanes only in conjunction with general geological studies and reconnaissance of areas of interest, rather than in a search for anomalies. This has decreased the number of anomalies discovered by the government and makes impractical the monthly posting of maps and their sale on subscription.

Posting time under the new arrangement will be announced by the AEC for each map. Maps will be posted at the following AEC offices, as well as at local places which may be announced.

Arizona—Phoenix Branch Office, 137 No. Second Ave., Phoenix. **Colorado**—Denver Area Office, Federal Center—Building 40, Denver 15. Grand Junction Operations Office, Grand Junction, Colo. **District of Columbia**—Library of Congress, Map Division, Washington 25, D. C. **Montana**—Butte Branch Office, P.O. Building, Room 315, Butte, Mont. **New Mexico**—Albuquerque Branch Office, 301 Washington St., S.E., Albuquerque, N. M. **South Dakota**—Rapid City Branch Office, Prep Building, School of Mines & Technology, Rapid City, S. D. **Texas**—Austin Branch Office, Balconnes Research Center, University of Texas, Austin, Texas. **Utah**—Salt Lake Area Office, 222 South West Temple Square, Salt Lake City. **Wyoming**—Casper Branch Office, 148 N. Beech St., Casper, Wyo.



'A Little Knowledge is a Dangerous Thing'

PERHAPS it is not twisting the meaning of this well turned phrase too much if, rather than applying it to an individual, we apply it to the problem of technical manpower. During the last five years or so, we have all felt the growing seriousness of the engineer shortage, whether it be by having to leave work to go on a tour of college campuses interviewing the ever more choosey graduating engineer, or by trying to expand plant facilities with an already overworked engineering staff of unchanging size.

To those directly concerned with hiring the nation's graduating mining engineers, the problem seems especially tough. Enrollments have not shown any increase, and the only solution seems to be to go out and campaign harder for the existing supply. Little reflection is necessary to realize that this is but another form of inflation—a text book example of supply and demand—and really no solution at all. No, the problem is certainly too large for any firm, or even any industry or professional society, to handle alone. Not that individual persons or firms do not want to help—but direction and wise counsel are needed, and there must be a definite plan.

There is such direction and wise counsel in the form of a group that you have more than likely heard of; it's often called EMC of EJC, and you'll probably hear considerably more of it in the coming months. EMC of EJC stands for Engineering Manpower Commission of the Engineer's Joint Council. It was founded in 1950 as a joint effort of several professional engineering societies, including the AIME. EMC has worked closely with other groups of similar nature, but in the realm of engineers and engineering problems, it is the primary organization.

EMC has three major goals: to demonstrate to the country the growing importance of engineering to economic development and national security; to promote effective utilization of engineers; and to encourage qualified students into our engineering schools.

Articles concerning the engineer shortage that you have read were probably prepared with the help of EMC information. Since 1951, EMC has been making annual surveys, checking the number of engineering degrees granted and the number of jobs available. Salary studies and reports of professional employment conditions have also been made. The fact that the salary scale of engineers in the federal government has been raised twice in three years speaks for the effectiveness of these reports.

For several years following the enactment of Universal Military Training, the greatest waste of our technical manpower was in the draft program, where qualified engineers were driving trucks and cleaning rifles. After much EMC agitation, the Critical Skills Law now allows many of these men to serve for the brief span of six months, and then return to their critical and defense supporting jobs. Progress is also being made toward the establishment of an Army Scientific Corps, along the same line as the Medical Corps, to insure full utilization of engineers and scientists in the army. Indeed, there must always be a foot soldier, but the complexities of military technology demand men to push sliderules rather than shovels to run the multi-billion dollar mechanisms of defense.

After the first five years of operation, EMC can be proud of its record. However, there are two fields, both of vital interest to all AIME members, in which results have been negligible. The first is enrollments. Although enrollment in many engineering fields during the past few years has been encouraging, mining engineering has not been one of these fields. This is a very serious problem, and it is hoped that through continuing efforts of the EMC, the firms of the mining industry, the newly formed President's National Committee for the Development of Scientists and Engineers, and the universities and colleges themselves, that this situation can be helped.

The second point is the utilization of engineers by private industry itself. A recent EJC report on professional standards and employment conditions emphasizes the importance of this aspect. It is a difficult job for any group to go to the leaders of industry and ask them to make an "agonizing reappraisal," to see if their professional employees are being used to their fullest capacity. Yet, statistics show that most engineers leave their jobs because they don't feel that they're doing what they were trained for, or that they were not getting recognition for that work. The job turnover figures for engineers less than three years out of college (or the army) are truly shocking.

America is currently undergoing an acceleration of technological advancement unparalleled since the very beginning of the industrial revolution. With hardly more than a scratch made upon the potential applications of atomic energy, one might imagine we were entering upon the very steep portion of an exponential curve. To meet these demands, a great number of men and women will be needed who are not only technically competent, but who are also alert, cognitive citizens. It is only through such organizations as the President's Committee and the Engineering Manpower Commission that this need shall be met.

J. J. Burke

Hydrometallurgy Of Uranium

by R. A. Foos

The most recent developments in the hydrometallurgical techniques for the processing of uranium ores are discussed. At the present time, ion-exchange resins are widely used for the recovery of uranium from either clarified or slime-bearing leach liquors. Current progress on the application of liquid extraction indicates that it could soon replace the ion-exchange technique. Various high molecular weight organophosphorus and organonitrogen organics have shown considerable promise as uranium (and vanadium) extractants from sulfuric acid solution. A description is given for both the currently employed ion-exchange method and the potential liquid extraction system.

DURING the radium boom in the early part of the twentieth century, the basic chemistry of uranium was fairly well defined. Uranium production has progressed from the status of a radium by-product to a very important industry. With the ever increasing need for more efficient and cheaper methods of processing uranium ores, new techniques are being developed. Since uranium and vanadium often occur together in nature, the latter element will also be considered. As production rates, costs, and certain aspects of uranium chemistry are still classified by the Atomic Energy Commission, these will not be discussed.

Domestic uranium deposits, in general, are composed of the minerals carnotite, which contains hexavalent uranium, and to a lesser extent, pitchblende and uraninite, which contain tetravalent uranium. Carnotite also usually contains vanadium. The uranium and vanadium contents of these ores vary considerably. The ores currently processed on the Colorado Plateau assay from 0.2 to 0.4 pct U and from trace amounts to 5.0 pct V. On the other hand, the phosphate rock deposits of the southeastern U. S., from which uranium is also recovered, contain only about 0.01 to 0.02 pct; processing of the phosphate rock deposits will not be considered. The Plateau ores also differ in lime and silica content. Because of these wide variations in composition, several hydrometallurgical procedures are being used commerically to recover uranium and vanadium from their ores.

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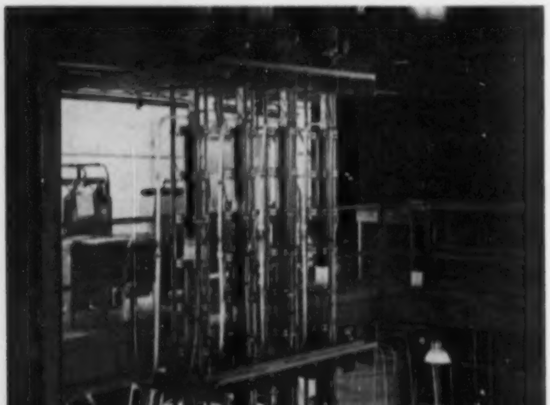
A process for the recovery of a reactor-grade uranium product from the Colorado Plateau ores may require the four general steps as illustrated in Fig. 1. These steps consist of ore upgrading by physical methods, solubilization of the uranium in aqueous media, selective removal of an impure uranium concentrate from the aqueous solution (greater than 75 pct U_3O_8), and purification of this concentrate to a reactor-grade uranium product. Physical concentration methods include flotation and heavy-media separations. Uranium dissolution is accomplished by either acid or alkaline leaches. The impure uranium concentrates are produced by precipitation, ion exchange, or liquid extraction techniques. (The term *liquid extraction* denotes that which is generally referred to as *liquid-liquid extraction.*) Reactor-grade uranium products are currently prepared from this concentrate by liquid extraction. Each of these processes will be reviewed with the main emphasis on the recovery of an impure uranium concentrate by liquid extraction and ion exchange.

Upgrading of Uranium Ores by Physical Methods—Attempts to produce uranium concentrates by physical methods have thus far shown little promise. However, low grade ores have been upgraded to so-called high grade ores by selective flotation of the uranium from some of its silicate-carbonate gangue. Uranium-bearing minerals have been floated by the use of either the American Cyanamid 800-Series reagents or octylorthophosphoric acid as a collector in an acid circuit.[1] By using this method, an 86.7 pct recovery of the uranium was realized from treatment of the deslimed pulp. For example, in one test the head samples assayed 0.13 pct U_3O_8, the tails 0.048 pct U_3O_8, and the concentrate (including slimes) 0.29 pct U_3O_8.

Lord and Light[2] have reported flotation of uranium by the use of either fatty acids or a petroleum sulfonate product. In this procedure, concentrates containing from 0.2 to 0.6 pct U_3O_8 were obtained from an ore assaying 0.10 pct U_3O_8. Uranium recoveries of from 85 to 98 pct were obtained. The reagent cost in this process varied from 15 to 30¢ per lb of uranium. Gaudin et al. have also reported uranium flotation with oleic acid.[3] In a few cases heavy-media separations have been reported for the separation of lime from the heavier uranium minerals.

In general, flotation methods result in the recovery of concentrates from low grade ores which, in terms of uranium content, resemble the currently processed so-called higher grade ores. Since the supply of ore suitable for direct treatment has not as yet been exhausted, flotation of domestic uranium ores has found little commercial application.



Pilot plant used for extraction of uranium ore by the ore solvent process, which is capable of recovering 15 to 20 different low grade ores that were too expensive to refine.

Fig. 1—Generalized process flowsheet for preparation of reactor-grade uranium from its ores.

Leaching of Uranium From Ores—In general, after proper conditioning, the raw ores are treated directly. Acid leaches are employed for treatment of high silica ores, while alkaline carbonate leaches are used for high lime ores. The presence of vanadium in the deposit complicates the process, since a sodium chloride roast is required to ensure its complete dissolution in the leach liquors.

Treatment of High Silica Ores: Because silica reacts with caustic soda or soda ash, an acid digestion circuit is used for recovering uranium from high silica ores. At the present time, sulfuric acid is used almost exclusively for this purpose. In a very few cases, hydrochloric acid has been used because of the ready availability of materials for its preparation.

Compounds of hexavalent uranium are much more soluble in aqeous solutions than those of tetravalent uranium; consequently, in the latter case, an oxidizing agent is often added to aid in dissolution. Manganese dioxide is widely used for this purpose, although chlorine, sodium chlorate, and hydrogen peroxide have also been used successfully. Domestic ores do not generally require this oxidation step, since most of the uranium is present in the hexavalent state.

As many uranium ores contain relatively large amounts of vanadium, it is sometimes economically desirable to extract both of these constituents. Direct acid leaches do not give a quantitative recovery of vanadium. In order to effect complete vanadium recovery, a roast of the ore in the presence of sodium chloride at about 850°C is used. This roast converts a portion of the vanadium into a water-soluble sodium vanadate, Na_3VO_4, while not increasing the solubility of uranium. As a result, part of the vanadium is recovered from the roast residue and, consequently, separated from the uranium by a water leach. Solubilization of the remaining vanadium and all of the uranium is subsequently obtained by a sulfuric acid leach. The uranium dissolves primarily as uranyl sulfate, UO_2SO_4, and the vanadium as vanadyl sulfate, $VOSO_4$. A

simplified flowsheet of this process is given in Fig. 2. If vanadium is not present in the ore or its recovery not desired, the sodium chloride roast is omitted.

The sulfuric acid leach solution obtained by this treatment has a pH of from 0.5 to 1.5 and contains about 0.3 to 2.0 g of uranium and from traces up to 5 gpl of vanadium. Many other elements are also present in appreciable quantities. The composition range for typical acid leach liquors is given in Table I. Essentially, a quantitative recovery of uranium and vanadium is effected by this process.

Treatment of High Lime Ores: Uranium is usually recovered from the high lime ores by leaching with an aqueous solution containing a mixture of sodium carbonate and sodium bicarbonate. In this treatment, the uranium is solubilized as sodium uranyl tricarbonate, $Na_4UO_2(CO_3)_3$, and the vanadium as sodium vanadyl tricarbonate, $Na_4VO(CO_3)_3$. The resulting solution has a pH of about 11 with a U-V concentration similar to that described for the acid leach liquors. However, the concentration of other elements in the solution is much lower, since the carbonate leach is more selective.

The recovery of uranium from its ores by an alkaline leach is generally slightly less efficient than by the acid treatment. In addition, the required particle size of the ore is somewhat smaller. As in the acid treatment, a sodium chloride roast is required if recovery of vanadium is desired. The addition of atmospheric oxygen to the carbonate solution aids in the solubilization of uranium. In general, corrosion and filtering problems are simpler for the alkaline treatment.

The leaching of synthetic uranium ores with a nonaqueous solvent[4] and with $(NH_4)_2CO_3$ has been reported.[5] In the former cases, alkyl phosphoric acids were used for this purpose. By such a technique, the high acid or alkali consumptions are eliminated and the liquid-solid separation problems decreased. The use of $(NH_4)_2CO_3$ permits recycling of NH_3 and CO_2 which are obtained from chemical processing of the carbonate leach solution. Many problems still exist although pilot plant operations have been reported.

Recovery of the Impure Uranium Concentrate from the Leach Solutions: As the AEC specifications for the acceptable uranium oxide concentrates are on a contract basis, they vary with each producer. In general, however, the concentrates must assay greater than 75 pct U_3O_8 (although an acceptable 65 pct U_3O_8 is known[6]) and contain only a limited amount of specified foreign elements. Typical specifications for an acceptable impure uranium concentrate are given in Table II. It can be seen from this table that most of the vanadium present must be separated from the uranium before the concentrate is marketable.

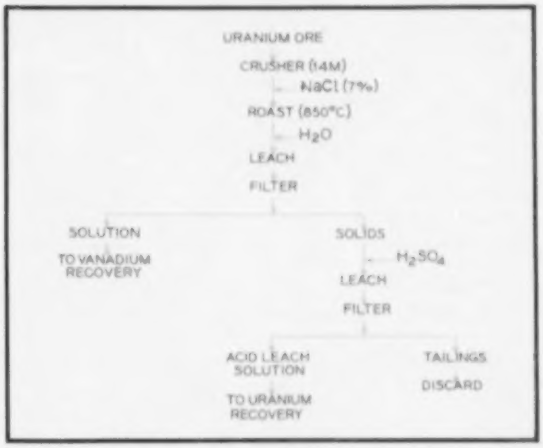


Fig. 2—Flowsheet for the uranium-vanadium recovery from their ores.

The methods for the recovery of a marketable uranium concentrate vary for the acid and alkaline liquors. Until about 1950, all of the leach liquors were treated by precipitation methods. However, since then, ion exchange has gradually replaced precipitation in the case of acid solutions. Direct treatment of the leach-solution-ore slurries, as well as the clarified liquors, has proved successful. Liquid extraction is now being considered as a replacement for ion exchange.

Treatment of Sulfuric Acid-Leach Solutions: Until recently, the recovery of uranium from sulfuric acid-leach solutions was carried out by either the aluminum sludge or the phosphate precipitation method. Both of these procedures require many critical and time consuming operations in order to recover a product of sufficient purity. For this reason, more economical and reproducible techniques were desired. Success of the ensuing work is demonstrated by the fact that only a small percentage of the companies on the Colorado Plateau now employ a precipitation technique.[6]

Ion Exchange—This method for producing an impure uranium concentrate has been studied in considerable detail for the past ten years. Most of the plants constructed on the Colorado Plateau during the past three years are employing ion exchange.[7] It can be used successfully for treatment of either clarified liquors or for solutions containing solids. The latter is called the resin-in-pulp method (RIP). There are at least five domestic commercial uranium processing plants which are either under construction or in the final design state, which are using, or plan to use, the RIP process.[8] Although the engineering of the two methods is different, the basic principles are the same. This represents the

Table I. Typical Analysis of Acid Leach Liquors

Component	Concentration, Gpl
U_3O_8	0.3 to 2.0
V_2O_5	0 to 5
Ca	0.5 to 2.5
Mg	0.5 to 2.0
Fe	0.5 to 4.0
Al	2.0 to 5.0
Si	0.1 to 1.0
N	0.1 to 1.0
P	0.01 to 0.1
SO_4	15 to 25
Cl	3 to 6

Table II. Typical Specifications for Impure Uranium Concentrates

Component	Pct
U_3O_8	>75
V_2O_5	0 to 5
P_2O_5	1.8
Mo	0.04
Fe	2.2
Cu	1.3
Pb	0.04
As	0.04
Na	0 to 10
Mg	0 to 10
Ca	0 to 10

first use of ion exchange in the field of extractive hydrometallurgy.

Uranium occurs in the sulfuric acid solution as the uranyl ion, UO_2^{++}. For this reason, cation-exchange resins were first investigated as uranium adsorbents. It was found that uranium was adsorbed completely on this resin. However, the resins were not selective, as Fe^{+3}, Fe^{+2}, Al^{+3}, Mg^{+2}, Mn^{+2}, and Ca^{+2} were also adsorbed strongly. Because of the lack of uranium selectivity, the use of cation-exchange resins for recovering uranium from sulfuric acid solutions is not employed.

In 1948, A. W. Bearse of Battelle Memorial Institute[6] reported that uranium could be extracted selectively from a sulfuric acid solution by a strong base anion-exchange resin. Because of the strong affinity of the uranyl ion for sulfate ions, the di and trisulfate complexes are present in the leach solutions. Their formation from uranyl ions are represented by Eqs. 1 and 2

$$UO_2^{++} + 2\,SO_4^{=} \rightleftharpoons [UO_2(SO_4)_2]^{=} \qquad [1]$$

$$UO_2^{++} + 3\,SO_4^{=} \rightleftharpoons [UO_2(SO_4)_3]^{4-}. \qquad [2]$$

These uranyl sulfate complexes have a strong affinity for certain strong base anion-exchange resins. Uranium is primarily adsorbed as the trisulfate complex, although the presence of the disulfate complex is also significant. The adsorption of the uranyl sulfate complexes by the resins causes a shift to the right in the equilibrium of Eqs. 1 and 2 to result in the formation of more adsorbable complexes. These anion-exchange resins also adsorb appreciable amounts of sulfate and bisulfate ions. However, as the resins become saturated with uranium, the sulfate and bisulfate ions are displaced by the uranyl sulfate complexes. Uranyl sulfate complexes will displace chloride, nitrate, and amino anions.

It has been found that the amount of uranium which the resin can adsorb increases with pH. This is explained qualitatively by the fact that bisulfate has a greater affinity than sulfate for strong base anion-exchange resins. Consequently, fewer resin sites are available for uranium adsorption in strong acid solutions where the formation of bisulfate ions is favored. These leach solutions are adjusted to a pH of 1.3 to 1.7 before the ion-exchange treatment.

The ion-exchange process, in general, consists of adsorption, elution, and the recovery of uranium from the resin strip solution, or eluate. Eqs. 3 and 4 give the overall adsorption reaction for a nitrate resin. R indicates the organic portion of the resin. As the acid leach solution passes through the column, nitrate ions are replaced by the uranyl sulfate complexes. The other elements present, in general, are not adsorbed and consequently pass on through the column.

$$2\,RNO_3 + [UO_2(SO_4)_2]^{=} \rightleftharpoons R_2UO_2(SO_4)_2 + 2\,NO_3^{-} \qquad [3]$$

$$4\,RNO_3 + [UO_2(SO_4)_3]^{4-} \rightleftharpoons R_4UO_2(SO_4)_3 + 4\,NO_3^{-}. \qquad [4]$$

After the ion-exchange resin is contacted with sufficient leach liquor to saturate it with respect to uranium, removal of the uranium from the resin is required. This is accomplished by treating the resin with acid solutions containing sodium or ammonium salts of chloride and/or nitrate. Uranyl sulfate complexes cannot be adsorbed from solutions which are more than 0.5 mol in chloride or nitrate ions. Consequently, the eluting solution is generally about 1 mol in these acids with a pH of from 1 to 2. The eluate not only strips the uranium from the resin bed, but also regenerates the resin to a reusable form. This elution step entails the reverse of the reactions given in Eqs. 3 and 4.

Uranium is recovered from the eluate, or uranium-rich solution, by direct precipitation. Addition of ammonia gives a product with small contamination, while the addition of magnesium oxide gives a precipitate easier to thicken and filter but containing substantial amounts of magnesium. The solution which results from the filtration of the precipitated uranium is reacidified and recycled to the ion-exchange resin saturated with uranium for stripping purposes. The impure concentrate attained by this method varies from 75 to 95 pct U_3O_8. An analysis of such a product is given in Table III. It is apparent that the 95 pct U_3O_8 concentrate (and a marketable product) was obtained in this case.

Table III. Analysis of Impure Uranium Concentrate From Ion-Exchange Treatment[7]*

Component	Pct
U_3O_8	94.6
Fe	1.3
Al_2O_3	0.36
SiO_2	1.92
SO_4	0.39
MgO	0.15
CaO	1.56
Mn	0.15

* NH_4OH precipitation used, vanadium was not present in the ore. When present, it constitutes up to 5 pct of the concentrate.

Although the ion-exchange method is technically superior to the precipitation technique, certain limitations to its use exist due to the adsorption of poisons. The small amount of iron which is absorbed can be eluted before uranium. On the other hand, some anions are more tightly held by the resin than the uranyl sulfate complexes.[7] As their concentrations build up, the capacity of the resin for uranium decreases, and the retention time of uranium in the column increases. These poisons include molybdates, silicates, cobaltic cyanide, polythionates, and pentavalent vanadium. The first four poisons are removed from the resin by periodic treatments with conditioned aqueous solutions. Prior reduction of the vanadium to the tetravalent state prevents its adsorption. All of these poisons can be removed without destroying the resin.

The recovery of vanadium from these acid-leach liquors is desired in many cases. Since tetravalent vanadium is not adsorbed, uranium is initially removed from the leach solution containing vanadium in the reduced state. Following uranium removal, the vanadium is oxidized with sodium chlorate, and then the leach liquor is passed through the resin bed. As stated previously, pentavalent vanadium is adsorbed by strong base anion-exchange resins. Elution of the vanadium-saturated resin with dilute sulfuric acid gives a product which is generally recovered as red cake, a vanadium oxide concentrate.[8]

During the operation of the vanadium cycle, high vanadium loading of the resin is obtained. Some red cake is often precipitated at the top of the columns although operation temperatures of from 50° to 60°C are used to decrease this tendency. Vanadium recoveries of 90 to 95 pct are obtained by ion-exchange techniques. The development of ion exchange for vanadium recovery is not as advanced

as for uranium; however, pilot plants have been operated successfully.[10]

The ion-exchange columns in the uranium mills are generally about 7 ft in diam and 12 ft high.[7] The resin beds have a depth of 5 ft and contain about 200 cu ft of the resin. Since resin beds double in volume during one cycle of the process, columns sufficiently large to contain the resins under such conditions of expansion are required. As the resins generally hold 2 to 4 lb of uranium oxide per cu ft, 400 to 800 lb of product are recovered per cycle.

In the usual operation, three columns are arranged in series.[11] Flow rates are adjusted so that the resin in the first column is just saturated with respect to uranium as the uranium starts to emerge from, or break through, the second column. At this point, the first column is removed from the stream and stripped of its uranium. The liquor emerging from the second column containing uranium is passed through the third column. When uranium breaks through the third column, the second column is saturated with respect to this element. In this way, while one column is being stripped, the other two columns are used for the adsorption of uranium. Although this ion-exchange technique is now operated on a semicontinuous basis, equipment has recently been developed, and will undoubtedly soon be in use, which closely simulates a true countercurrent process.

As an example of typical production rates and scale of operation for three columns with the dimensions described previously, a 15-hr process cycle will be considered.[7] During this time, 97,000 gal of leach liquor containing 405 lb of uranium oxide were processed. Approximately 10,000 gal of eluate were recovered containing 404 lb of uranium. The equivalent uranium oxide concentration in the eluate was 49 gpl representing a 99.8 pct recovery of the uranium.

Although the extraction of uranium and vanadium from clarified acid liquors by ion-exchange resins is successful, the RIP technique is becoming very widely employed. This method involves grinding and leaching of the ores, desanding the pulp, and selective recovery of the solubilized uranium by contacting the slime-bearing leach liquor with anion-exchange resins. The resins are contained in a wire basket of such a mesh size as to permit flow of the slimes through the screen and yet retain the resins. The resins are moved in an up and down manner in the tanks (called banks) through which the pulp flows. The pulp feed is advanced from tank to tank to give a countercurrent effect. Elution of the uranium-saturated resin is carried out in an analogous manner. The rate of uranium adsorption by the resin is unaffected by the presence of slimes in the leach liquors. After two years of operation, resin losses due to attrition were about 23 pct with a decrease in loading capacity of about 10 pct.[8] The concentrates recovered from the eluate streams contain greater than 99 pct of the uranium and assay from 75 to 95 pct U_3O_8.

In general, about six banks are required for complete removal of uranium from the solutions. A similar number of banks are used in the elution cycle of the operation. The largest banks which have been tested, 6x6x6 ft, contained 50 cu ft of resin and produced a satisfactory uranium concentrate.[8] Such banks are operated continuously by alternating from adsorbent to eluate streams as required.

Pilot plant data have indicated that vanadium can be recovered in yields of 90 to 95 pct by the RIP process.[10] The operating conditions and results were similar to those described for treating clarified liquors.

It is apparent that the RIP process eliminates many of the solid-liquid separation problems. Since settling and filtration behavior vary considerably from ore to ore, the elimination of these operations is very desirable. Because of the versatility of the RIP method, it is possible that this technique could replace conventional treatment of clarified liquors. However, many new flocculating agents are being developed and tested in order to decrease these filtration problems. If successful, this will minimize one of the main advantages of the RIP process.

Liquid Extraction—Separation by liquid extraction requires the selective transfer of solutes between immiscible, or partially immiscible, liquid phases. This, in most cases, requires the mixing of an organic liquid having a low solubility in the aqueous phase with an aqueous solution containing a mixture of solutes. Conditions for the selective transfer of solutes are required. Since the complete separation of solutes is generally not obtained in a single contact of the two phases, a number of extractions, properly carried out, are required. Many commercial liquid extractors are available to carry out this process on a continuous basis.

In determining the utility of an organic reagent in liquid extraction, certain requirements are necessary. It is obvious that high selectivity for the desired elements is necessary. A reagent is considered selective if it results in the extraction of one element, or group of elements, to a much greater extent than for other elements in the system. Adjustment of aqueous phase conditions is necessary to obtain optimum selectivity and separation. The price that can be paid for an extractant is contingent almost completely upon its recoverability. It is obvious that a high priced organic might be employed if quantitative recycling were ensured. In treating uranium solutions, the loss of only trace amounts of organic reagents is permissible, since the leach liquors are very dilute in terms of uranium concentration. In order to enhance recoverability, the organic extractant should be quite soluble in organic media and insoluble in aqueous solutions. Chemical and thermal stability is also necessary for effective recoverability. A specific gravity difference between the organic and aqueous phases is desired for rapid phase separation. Viscosity of the organic and aqueous phases should be low to decrease emulsification tendencies and yield clear equilibrium phases.

As a result of work by Brown and coworkers[12-14] at the Oak Ridge National Laboratory, several liquid extraction procedures for the recovery of uranium and vanadium from acid solutions have been developed. During the course of this investigation, many varying types of organic reagents were studied. Certain organonitrogen and organophosphorous compounds were found to possess high selectivity for uranium and vanadium. Adjustment of conditions permits good separation of these elements from each other. Essentially two methods have evolved. These are called the dialkylphosphoric acid process (DAPEX) and the amine extraction process (AMEX). There is currently considerable debate as to which, if either, of these methods is economically and technically superior.

At the present time, these methods are being tested by at least five domestic producers of uranium." It is believed by many that liquid extraction will soon replace ion exchange for the recovery of uranium and vanadium from acid-leach solutions.

DAPEX Process—The testing of many organophosphorous compounds has been reported for extraction of uranium and vanadium from acid solutions. Both neutral and acid reagents have shown promise. These compounds include mono, di, and trialkyl phosphates, alkyl phosphoric and phosphenic acids and their esters, alkyl phosphites, phosphine oxides, and alkyl diphosphates and diphosphonates. One of the most promising of these systems entails the use of di(2-ethylhexyl) phosphoric acid as the organic extractant. Because of engineering consideration, this organic extractant is dissolved in an inert solvent, such as kerosene, prior to extraction.

In the DAPEX process, sufficient alkyl acid phosphate is generally dissolved in the carrier solvent to give a 0.1M solution. Upon contact of this dilute extractant solution with the acid leach liquor, the reaction as given in Eq. 5 ocurs. R refers to the alkyloxy radical. It has been observed that the maximum selective extraction of uranium is obtained at a pH of about one. Since Fe^{+3} also extracts to an appreciable extent, it is necesary to reduce it to the ferrous state prior to extraction. Vanadium, which is also extracted by the acid phosphate, is transferred to a much lower extent than uranium under these conditions.

$$2\,R_2P(O)OH + UO_2SO_4 \rightleftharpoons UO_2[R_2P(O)O]_2 + H_2SO_4 \qquad [5]$$

Uranium will also displace vanadium as the organic phase becomes saturated with these two elements. None of the other elements, with the exception of molybdenum and titanium, extract to any appreciable extent. About three to five stages of extraction are required for transfer of 99.9 pct of the uranium from the sulfuric acid-leach liquor to the organic phase. The 0.1M-saturated organic phase contains from 8 to 10 gpl of uranium. Fig. 3 shows a simplified flowsheet of this process.

In order to strip the uranium from the organic phase, the reaction as given by Eq. 5 is reversed. This is accomplished by contacting the organic phase with aqueous solutions of ammonium carbonate, sodium carbonate, concentrated acids, or slurries of lime or magnesia. Recovery of the uranium in the strip solution is carried out by the conventional methods. The product purity varies with the extraction conditions and composition of the leach liquor. Generally, an oxide concentrate containing greater than 99.8 pct of the uranium and assaying greater than 95 pct U_3O_8 is produced. With additional liquid extraction steps, the purity of the concentrate can be increased. This purity excludes the possible contamination by precipitating agents whose contents are easily controlled.

Although vanadium does not extract to any appreciable extent at a pH of 1.0, such is not the case at a pH of from 2 to 3. At this acidity, vanadium is easily extracted by the alkyl phosphoric acid. In order to enhance vanadium extraction, the reagent concentration in the organic is increased to about 0.4M. Stripping of the organic, followed by precipitation, gives a high purity vanadium product. The vanadium cycle, engineering-wise, is quite similar to the uranium cycle.

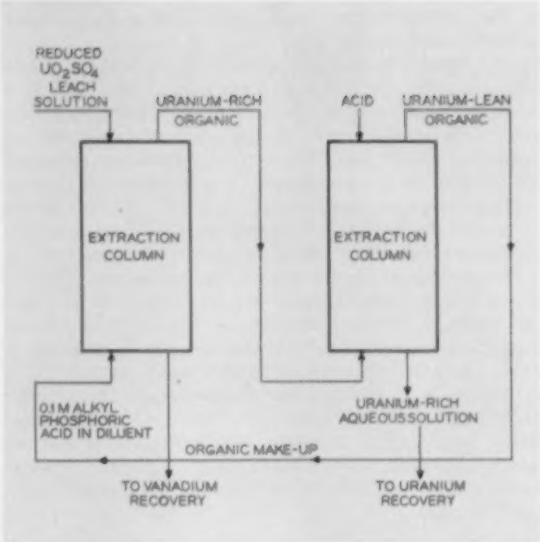


Fig. 3—DAPEX liquid extraction process for uranium recovery from acid solution.

AMEX Process—Over 200 amines have been screened at the Oak Ridge National Laboratory as extractants of uranium from acid solutions. In order to meet solubility requirements, these have been limited to the long chain derivatives. Secondary and tertiary amines have been reported to be technically superior to primary amines. Chain branching also aids in uranium extraction. In order to compare the extractability by some of these amines, several distribution coefficients of uranium, K_U, are given in Table IV. The distribution coefficient for uranium is defined as the ratio of the metal concentration in the organic phase to that in the aqueous phase at equilibrium. The organic phase was a 0.1M amine solution in kerosene. It can be seen from these data that the high molecular weight secondary and tertiary amines show favorable uranium extractability.

The number of ideal stages required to reduce the uranium content of the aqueous phase from 1.25 to 0.001 gpl has been reported. When extracting with Rohm & Haas amine 9D-178 (K_U 70), about 2.9 stages are needed at a flow ratio of 2.7 vol of aqueous per vol of organic. For comparison purposes, 1.9 stages are required while employing N-benzyl-1(3-ethylpentyl) 4-ethyloctyl amine (K_U>2000). Consequently, for distribution coefficients over 70, the stage requirements do not change appreciably. Table V shows some of the amines which to date are considered as likely candidates for uranium process application.

In determining the uranium loading capacity for the secondary and tertiary amines, the reactions as

Table IV. Extraction of Uranium from H_2SO_4 Solution with 0.1M Amine

Organic	K_U
Rohm & Haas primene JM-R	0.014
Di-2(2-butyloctyl) amine	70
Rohm & Haas amine 9D-178	70
UCC amine S-24	120
N-benzyl-1(3-ethylpentyl) 4-ethyloctyl amine	>2000
Tri-n-octyl amine	200

shown in Eq. 6 and 7 are presumed to occur. It is probable that the amine extractant operates as a liquid ion-exchange resin. This would require initially the formation of amine-sulfate (or bisulfate) salt followed by displacement of the sulfate (or bisulfate) with the di or trisulfate uranyl anion. A 0.1M amine solution in an inert diluent, such as kerosene, dissolves from 4.0 to 5.0 gpl of uranium. Higher uranium content of the organic phase is obtained by increasing its amine concentration. However, this introduces emulsion and selectivity problems. The use of hydrocarbons as diluents results in better extractability than oxygenated or polar diluents.

$$R_2NH + UO_2SO_4 \rightleftharpoons R_2NH \cdot UO_2SO_4 \qquad [6]$$

$$R_3N + UO_2SO_4 \rightleftharpoons R_3N \cdot UO_2SO_4. \qquad [7]$$

As indicated previously, the major impurities in the uranium leach liquors are iron, aluminum, magnesium, sodium, and vanadium. Extraction of Fe^{+3} is dependent upon the amine type and structure, while Fe^{+2} does not extract in any case. Tertiary amines and secondary branched amines do not extract Fe^{+3} to any appreciable extent. Molybdenum extracts to an extent almost equivalent to uranium but occurs in small amounts, can be stripped from the organic, and easily separated from the uranium by chemical methods.

The exact conditions for extracting vanadium by amines from the uranium-free leach liquors have not been reported. However, in general, the process entails oxidation of the vanadium to the pentavalent state, adjustment to a pH of two by addition of a base, and an extraction with the amine solution. Most of the work on vanadium extraction has been carried out with Rohm & Haas amine 9D-178 dissolved in kerosene. A high purity vanadium will undoubtedly be recovered by this process.

Comparison of DAPEX and AMEX Process—In both the DAPEX and AMEX processes, the recovery of greater than 99 pct of the uranium is obtained. Typical analyses, as given in Table VI, show that a fairly high quality uranium product is obtained. These liquid extraction uranium concentrates are generally higher in grade than the corresponding product from ion exchange.

The decision as to which, if either, of these two liquid extraction processes is superior requires the results of pilot plant operations. Sufficient data have not been obtained, or at least are not available, at this time. However, from a technical standpoint, a few comparisons can be made. In the DAPEX process, the iron must be reduced to the ferrous state to prevent its extraction. This is not required in the AMEX process. Uranium can be more easily stripped from the amine solutions than from the corresponding alkyl phosphoric acid solutions. Amines are reported to be more stable to hydrolysis and slightly more selective for uranium. However, the alkyl phosphoric acids are currently available in large quantities at a cost of about 50¢ per lb. At the present time, the amines considered for use are listed at about $2.00 per lb, although their projected cost is believed to be about one half of this if their use increases. Reagent losses, which are due to such factors as solubility in the aqueous phase, entrainment, or degradation, must be low for economic operation. In general, about 0.03 to 0.10 lb of organic complexing agent is lost per pound of uranium produced. The losses for the alkyl phosphoric acid extractants are reported to be slightly higher than for amines, although the choice of organic could alter this situation.

To indicate typical reagent costs in the liquid extraction process, a calculation of Brown's is given in Table VII.[16] Although chemical costs vary with the system, these data are indicative of the general extraction method. These chemical costs consider only the recovery of the uranium concentrate from the acid leach liquors. It is apparent from these costs that the organic reagent constitutes about 30 to 50 pct of the total chemical costs. It can also be seen that the total chemical cost is only 6 to 8¢ per lb of U_3O_8. This indicates the possibility of extending liquid extraction to the economical recovery of many other of the more common elements.

Treatment of Alkaline Leach Liquors—The recovery of uranium from alkaline leach solutions is somewhat simpler than from the acid leach liquors because fewer impurities are solubilized during the carbonate treatment of the ore. In general, a change in pH is employed to effect the precipitation of the uranium. This entails the precipitation of either sodium uranyl vanadate or sodium polyuranates.

In the former method, sodium carbonate solutions of uranium and vanadium are neutralized with sulfuric acid to a pH of from 3 to 5. As the carbon dioxide is boiled off, a quantitative precipitation of uranium as sodium uranyl vanadate is obtained. This solid, called yellow cake, is further refined to form U_3O_8. Vanadium is in excess if the stoichiometric amount required to precipitate the uranium stays in solution. It is precipitated as the sodium metavanadate by addition of alkali.

Uranium is also precipitated from the carbonate solution as a sodium polyuranate by the addition of caustic in excess of that required to neutralize the bicarbonate ion. Although this precipitation method

Table V. Promising Amine Extractants for Uranium

Name	Classification
Rohm & Haas amine 9D-178	Secondary
Tri(iso-octyl) amine	Tertiary
UCC amine S-24	Secondary
Tri(n-octyl) amine	Tertiary
N-benzyl-1(3-ethylpentyl)-4-ethyloctyl amine	Secondary
Di-(tridecyl P) amine	Secondary
Armeen 2-12	Secondary

Table VI. Typical Analyses of Uranium Concentrates From Liquid Extraction

Component	Pct
U_3O_8	95 to 99
V_2O_5	0 to 2
P_2O_5	<0.1
Mo	<0.1
Fe	<0.2
Cu	<0.1
Pb	<0.1
Si	<0.2
Mn	<0.1
Na	0 to 10
Mg	0 to 10
Ca	0 to 10

Table VII. Reagent Cost for AMEX Process

Chemical	Usage Lb per Lb U_3O_8	¢ per Lb U_3O_8
NaCl	2.3	1.9
H_2SO_4	0.2	0.3
NH_3	0.25	1.6
Amine and kerosene	—	2 to 4
		Total 6 to 8

is not quantitative, it is not critical, since the strip liquor is regenerated and returned to the leaching circuit. Uranium precipitates, which result from this treatment, are generally leached with a hot caustic solution. This dissolves substantial amounts of phosphates and impurities such as alumina, silica, and vanadium, while not affecting the uranium.

Another method of recovering uranium from these liquors entails the addition of hydrogen under pressure in the presence of powdered nickel to the alkaline solutions at 150°C.[18] The sodium uranyl tricarbonate is reduced to uranium oxide. After filtering of the uranium oxide, the filtrate is recycled to the circuit.

Ion-exchange techniques (RIP and clarified liquor) for separating uranium from these alkaline solutions have been reported.[8] This work is in the pilot plant stage. Several problems still exist, but the data are reported to appear promising. No liquid extraction methods of recovery of uranium from alkaline solutions have been reported.

Preparation of Reactor-Grade U_3O_8—In order to convert the impure uranium concentrates into a reactor-grade product, another liquid extraction process is employed. The impure uranium concentrates are digested in nitric acid, as indicated by Eq. 8, to form an aqueous solution of uranyl nitrate. The uranium solution, without filtration, is extracted with an organic solution such as tributyl phosphate in kerosene.

$$U_3O_8 + 8HNO_3 \rightleftharpoons 3UO_2(NO_3)_2 + 2NO_2 + 4H_2O. \quad [8]$$

This organic liquid preferentially extracts uranium from the aqueous slurry. The uranium-organic solution is extracted with water to produce a highly purified aqueous solution of uranium. Eq. 9 shows the extraction step of the process. During the stripping step, the operation proceeds in the reverse direction.

$$UO_2(NO_3)_2 \cdot 6H_2O + 2(C_4H_9O)_3PO \rightleftharpoons UO_2(NO_3)_2 \cdot 2(C_4H_9O)_3PO + 6H_2O. \quad [9]$$

Uranium is recovered from the aqueous nitric acid solution by evaporation followed by thermal decomposition of the uranyl nitrate. The denitrated product is UO_3, as shown by Eq. 10. Since this process has been carried out in a number of installations, the manufacturing techniques are well known.

$$UO_2(NO_3)2 \cdot 6H_2O \rightarrow UO_3 + 2NO_2 + \tfrac{1}{2}\, O_2 + 6H_2O. \quad [10]$$

The process efficiency is high with recirculation of most of the chemicals. At the present time, liquid extraction is the only method employed for preparing reactor-grade products. The AEC is now entertaining bids for private industry to produce up to 5000 tons of high purity U_3O_8, or its equivalent, per year. This request may stimulate the appearance of other processes.

Future of Uranium and Its Hydrometallurgy—The recent McKinney report on the *Impact of Peaceful Uses for Atomic Energy* pointed out quite vividly that industrial atomic power is not just around the corner. However, it was predicted that by 1980, about 90 pct of the new power plants will be based on nuclear energy, although only 8 pct of the total energy will be atomic. Some uses for irradiation and fission products are showing industrial promise with many more in the research stages.[19] As concluded in the McKinney report, it appears that this is only the preliminary stage of an industrial atomic age.

With the probable coming of a free uranium market, as requested in the McKinney report, development of new or improved hydrometallurgical techniques will certainly occur. As the mineral deposits become lower in uranium, flotation methods for upgrading will become more important. Although details of the cost picture are not as yet available, it is probable, based on current indications, that liquid extraction of uranium will gradually replace the ion-exchange methods. Presumably, many of the fully amortized ion-exchange plants will still continue to operate without technological changes. New, more selective, and cheaper organic reagents should be developed to extract uranium. It is possible that with somewhat greater selectivity and additional stages, very high purity, or even reactor-grade uranium may be produced directly from the dilute leach liquors. Elimination of the tributyl phosphate extraction would reduce considerably the manufacturing costs of the reactor-grade product.

As a result of the success of the RIP process, an analogous technique, the solvent-in-pulp process (SIP method), is being investigated.[20] Although details on its success are not available, it appears that uranium recoveries should be nearly quantitative. As in the RIP process, some of the liquid-solid separation problems are eliminated by this technique, although entrainment of solvent in the pulp could present a serious engineering difficulty.

Technology pertaining to the hydrometallurgy of uranium has advanced rapidly during the past five years. With the need for uranium apparently increasing, there seems but little doubt that the next few years will bring additional efforts and further significant developments in this very important industry.

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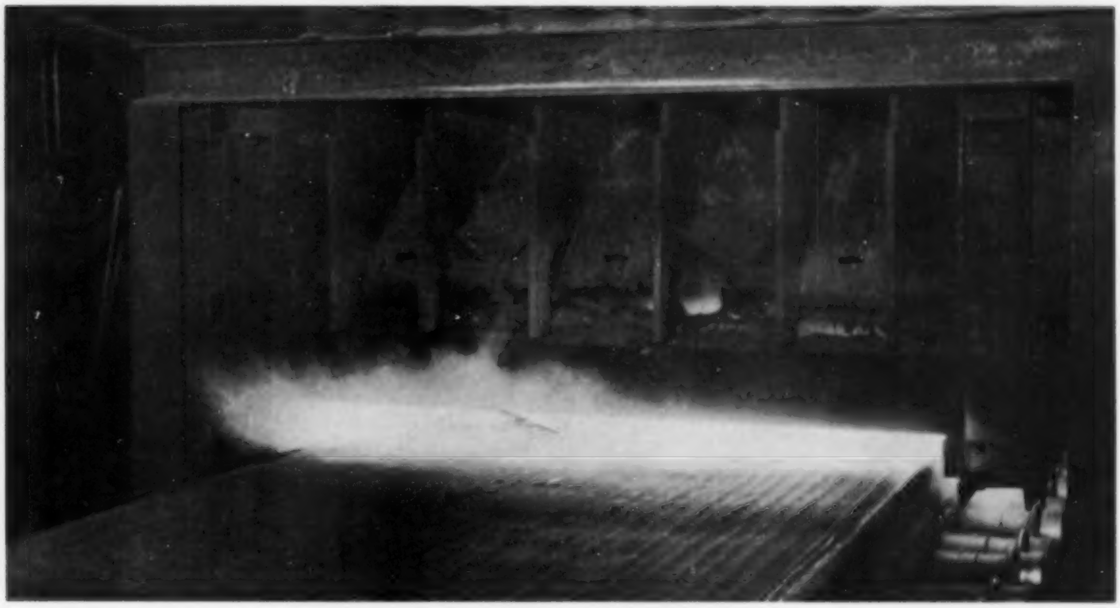

J&L's Star Lake Sinter Strand

by R. G. Fleck and F. M. Hamilton

AS the result of extensive small laboratory experiments, the metallurgical results of sintering iron ore from the Benson mines at Star Lake, N. Y. were clearly defined. But the practical operation had not been proved; so, the sintering strand, which went into operation at the mines in 1952, was designed to minimize the risk involved. It was built by the Dwight-Lloyd Div. of McDowell Co. Inc.

Sintering Machine

The hot section of the sintering strand, consisting of 16 windboxes, is 112-ft long, while the cooling section, which includes 5 windboxes, is 35-ft long, and the machine has a width of about 6½ ft.

The hot section of the strand is serviced by a No. 23 Double Inlet American Blower fan, 115 in. diam, which is driven by a 1000-hp motor equipped with a hydraulic coupling to the fan. The rated flow of gas per sq ft of hearth area is 229 cfm.

The cooling section of the strand is serviced by a No. 19 Double Inlet American Blower fan, 91 in. diam. It is driven by a 500-hp motor equipped with a hydraulic coupling. Rated flow of gas per sq ft of hearth area is 375 cfm.

Dust collection in both the hot and cooling sections is by means of American Blower No. 51 cyclones. Four cyclones, arranged in parallel, service the hot section, while two cyclones service the cooling section. The drive motors of each fan are cooled

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Fig. 1—Feed end of control panel. Vacuum readings for each windbox are indicated on left-hand side of panel.

Fig. 2—Air cooled sinter.

and air cleaned by a 380-watt Westinghouse Precipitron.

Raw Materials

The plant usually treats what are called martite concentrates, although it has operated at times on finer magnetite concentrates. Martite is the product of a spiral concentration process and originally came from the portion of the crude ore containing too much nonmagnetic material to make treatment in the magnetic concentrator practical. Typical screen and chemical analyses of the concentrates are given in Table I.

Fuel: No. 5 buckwheat anthracite culm is used for fuel in the mix, and No. 2 fuel oil is used for ignition.

Handling of Raw Materials: The raw materials are stored in four reinforced concrete silos. Three silos of 785 tons capacity each are used for concentrates and one silo of 185 tons capacity for anthracite culm. Each concentrate silo is equipped with a double-discharge 72-in. table feeder, Fig. 3, and the coal silo is equipped with two 24-in. wide belt feeders.

Mix ingredients are transported by two parallel 24-in. conveyors, leading to the pugmills located

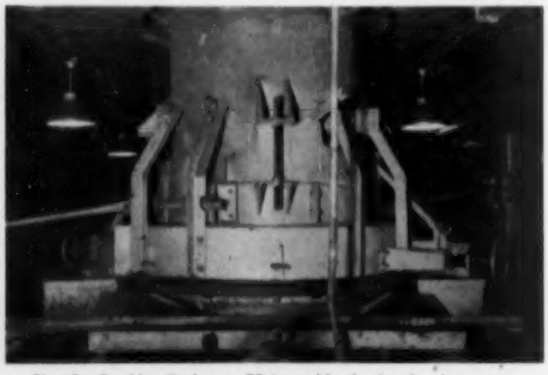


Fig. 3—Double discharge 72-in. table feeder for iron concentrate.

above the strand floor. Returns are added to each belt between the silos and pugmills. The mix is delivered to the strand in two separate streams, with fuel and water contents adjusted as required. The mixes are metered to the bed by roll feeders, Fig. 5. The third roll feeder is also available to feed a hearth layer to the strand.

The plant was designed to screen and crush returns to provide sized material for use as a hearth layer and as a mix ingredient for improving bed permeability. Returns from the grizzly at the discharge end of the strand are conveyed to a 4-ft by 10-ft vibrating screen. Undersize material (−⅝-in.) from the screen is sent to the strand. Oversize material is crushed in a 36-in. cone crusher with a ⅝-in. setting, and the crushed returns are combined with the original undersize product. The entire load of returns is conveyed to another screening station ahead of the strand. At this station, the returns are screened to ⅜-in., the oversize going to the strand as a hearth layer and the undersize being added to the mixes before pugmill treatment.

Handling Product

The product of the strand is partially air-cooled sinter, which requires only a little water to prevent damage to the paint of the railroad cars. When discharged, the sinter cake falls on a grizzly having 1-in. spacings and then to railroad cars for shipment to steel plants at Pittsburgh, Aliquippa, and Cleveland. Fig. 2 shows typical sinter from this operation, while Fig. 4 shows water-quenched sinter from the other strands.

Discussion of Results

Air Cooling: At the time this plant was designed, research had shown the desirability of producing an air-cooled sinter. After investigation of the various possibilities, it was decided to extend the strand length beyond the original planned length and use this portion of the strand for air cooling. Separate wind systems were provided for each section of the combined strand, even though the transition from the burning to the cooling area merely involved

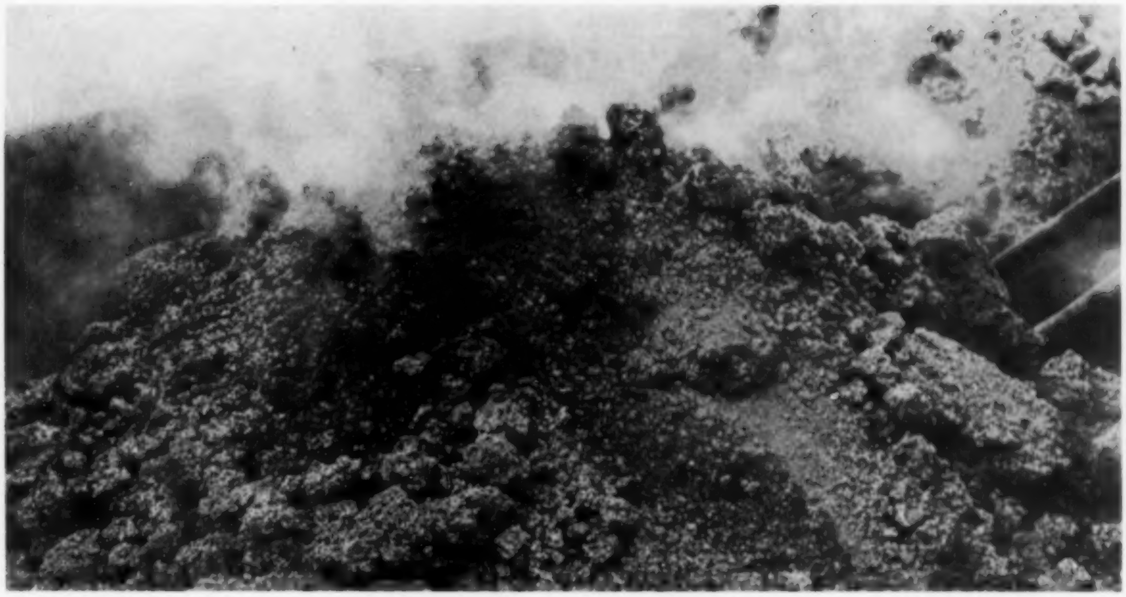


Fig. 4—Water quenched sinter.

movement of the pallet to an adjoining windbox. Thus it was felt that if the air-cooled sinter did not seem worth while to the consumers, the air cooling section of the strand could be used for burning and automatically provide increased sintering capacity.

The air-cooled sinter is highly satisfactory, and today it is a preferred product. In view, however, of more recent developments in air cooling equipment, strand cooling might not be the most efficient method to use. For future installations, consideration will be given to other types of cooling practices.

Sized Returns: The plant was designed to provide sized returns for the system, large returns for a hearth layer and smaller returns to promote bed permeability. It was found that air-cooled sinter made in this fashion would not normally provide enough returns, because of its greater resistance to breakage and abrasion. Wear of screens and crushers proved to be considerable. Therefore, while the use of a hearth layer of large returns and smaller returns in the mix is still felt to be attractive, the benefits obtained do not justify the cost of maintenance. For these reasons, the sized return system is not now used at Benson mines.

Multiple-Mix Layers: The two-layer charge system makes it possible to take some advantage of two well-known facts: water vapor condenses in the lower and cooler layers of the mix, and the oncoming waste heat from above provides part of the necessary heat for fusion. Theoretically, a mix in which the fuel and water could be arranged in the proper gradation from top to bottom, between some known limits, would be best for sintering. Lacking a practical method of attaining such a condition, this strand was provided with means for metering two separate and distinct mixes, one on top of the other. The bottom layer is run lean in moisture and fuel. The result is a smoother operation, some savings in fuel, and a more uniform product.

A byproduct of the two-layer system is some saving of downtime. Pugmills require considerable maintenance, and while one pugmill is off for repairs it is possible to run the strand on mix supplied entirely by the other pugmill and metering system.

Table I. Typical Analyses of Martite Concentrates

Chemical Analysis, Pct	
Iron (soluble)	60.52
Silica	6.14
Phosphorus	0.165
Sulfur	0.270
Titania	1.93

Screen Analysis

Mesh	Pct Wt	Cum. Pct Wt
+ 14	0.4	0.4
+ 20	4.5	4.9
+ 28	14.9	19.8
+ 35	19.4	39.2
+ 48	18.9	58.1
+ 65	17.7	75.8
+100	12.2	78.0
−100	12.0	100.0

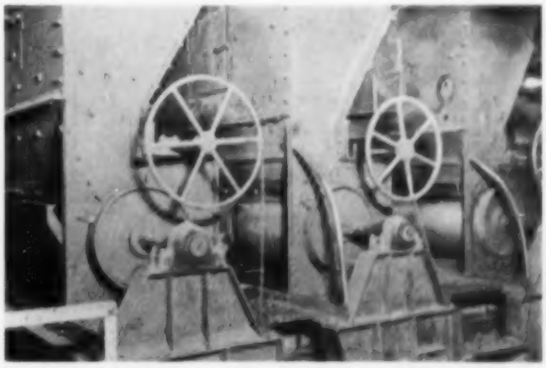
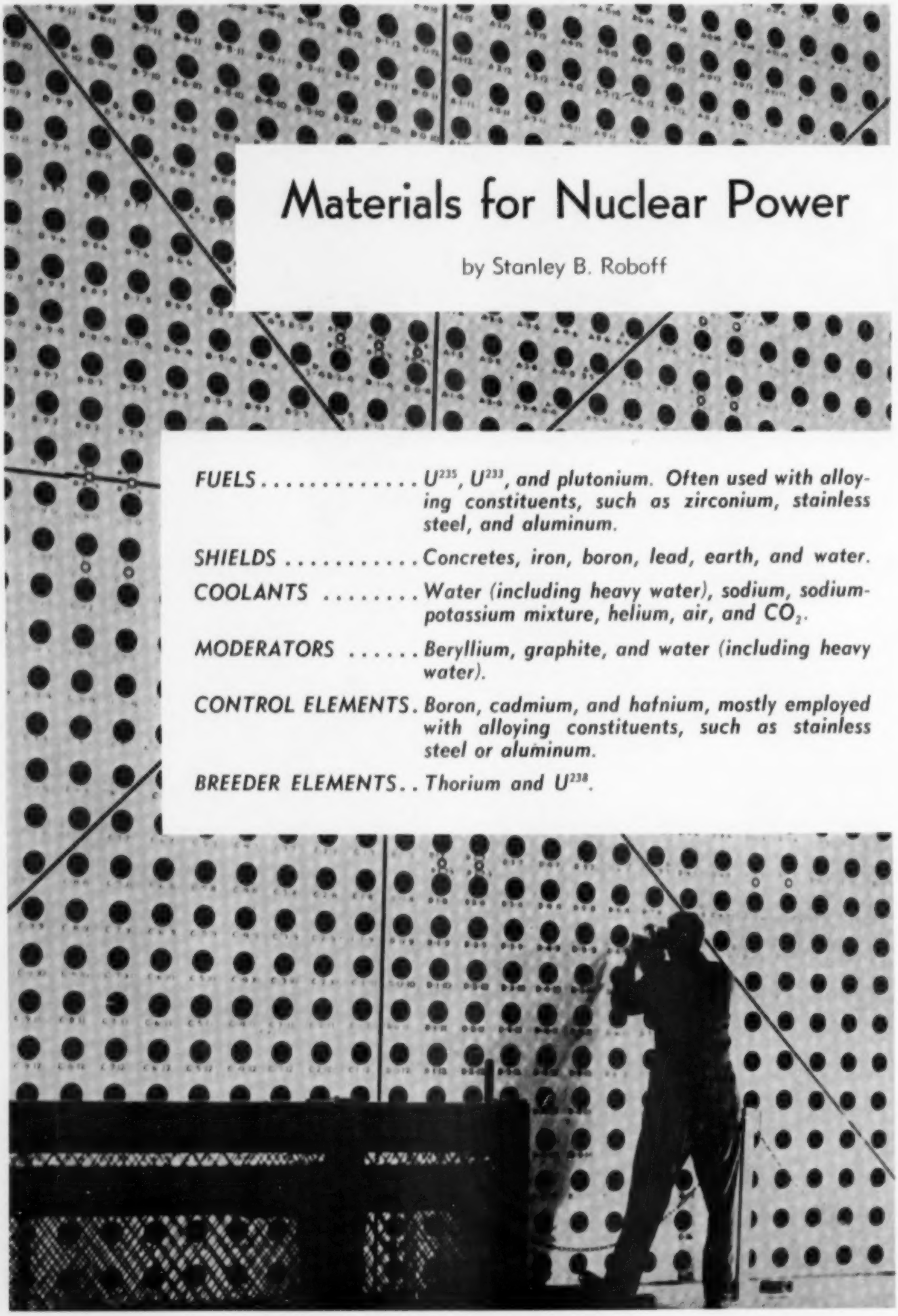


Fig. 5—Roll feeder for metering sinter mixes to the strand bed.

Materials for Nuclear Power

by Stanley B. Roboff

FUELS	*U^{235}, U^{233}, and plutonium. Often used with alloying constituents, such as zirconium, stainless steel, and aluminum.*
SHIELDS	*Concretes, iron, boron, lead, earth, and water.*
COOLANTS	*Water (including heavy water), sodium, sodium-potassium mixture, helium, air, and CO_2.*
MODERATORS	*Beryllium, graphite, and water (including heavy water).*
CONTROL ELEMENTS	*Boron, cadmium, and hafnium, mostly employed with alloying constituents, such as stainless steel or aluminum.*
BREEDER ELEMENTS	*Thorium and U^{238}.*



THROUGHOUT the world nuclear power reactors are being designed and constructed as the energy source for stationary power plants. They are built to power submarines, surface ships, and long-range aircraft and to provide small package power plants that can be set up with relative ease in outlying areas.

Regardless of type, most of these plants are designed to operate at the highest permissible temperatures and with the greatest possible burn-up of fuel. On paper it is now possible to design a nuclear power plant that will out-perform all existing types of power-generating plants, and at costs which are attractive. Such plants, however, are not now being built, nor will they ever be built, unless major engineering advances are made in the realm of reactor materials. The reason for this is straightforward enough. Although it is known that huge quantities of energy can be generated in nuclear fuels within short periods of time, as yet there are no construction materials capable of withstanding the severe conditions that would exist within a power reactor operating with ultrahigh output.

To put this another way, the theory of nuclear power generation is no longer an obstacle in achieving efficient and low-cost nuclear power. Materials, primarily, cause the bottleneck.

• A brief description of the basic components of a reactor will lead to better appreciation of the specific function of materials in a reactor and just why a high degree of performance is necessary.

• Among these major components **fuel** is of prime importance. Reactor fuels must contain a fissionable material, such as U^{235} or plutonium, in such quantities and geometries that a controlled nuclear chain reaction can be sustained.

• A second important component is the **coolant.** The coolant is a fluid which passes over, or through, the reactor fuel to pick up the heat generated within the fuel and transport this heat out of the reactor. It is this heat transported by the coolant which is used to generate steam and, ultimately, the desired power.

• A third component now used in a majority of reactors is known as the **moderator.** Moderators are used in certain reactors to slow down the speed of neutrons formed as a result of fission in the nuclear chain reaction. This enables the neutrons to be easily captured by another fissionable atom making it possible for the chain reaction to be sustained.

• Another important reactor component is the **control element,** usually a rod or plate inserted into the reactor core to soak up all neutrons in excess of those needed to maintain a controlled chain reaction at any particular level. A control rod is made up of a material possessing a high affinity for neutrons. Materials with a high tendency to capture neutrons are said to have a high *neutron cross section.*

• The reactor **shield** is a fifth important component. The intense nuclear and electromagnetic radiations generated in the core of a nuclear reactor must be intercepted, so that it will be completely safe for the reactor to operate in a confined area and so that operating personnel can work in close proximity to the reactor. Materials comprising the shield must be capable of absorbing the various types of radiation that emanate from the reactor core itself.

• An optional component is known as the **breeder element.** Some reactors are designed not only to produce power, but also to regenerate a certain amount of new fissionable materials. This is often possible, since some of the neutrons generated in a nuclear chain reaction can be used to convert materials such as U^{238} and thorium into plutonium and U^{233}, respectively. Whereas U^{238} and thorium are not ordinarily considered fissionable materials, the end products of reactions of U^{238} and thorium with neutrons, namely plutonium and U^{233}, are fissionable. For this reason U^{238} and thorium are called *fertile* materials. A large number of power reactors are designed for the incorporation of fertile materials within the reactor to soak up surplus neutrons and be converted into more valuable fissionable materials.

Nuclear Reactors: Fig. 1, a schematic drawing of a very simple reactor, will serve to explain the basic geometry. The single cross-hatched areas represent fuel rods, which are placed at regular intervals in a larger opening known as a coolant channel. Enough fuel rods are placed in the reactor so that a critical mass is achieved. Note that there is enough space between the fuel rod itself and the inside diameter of the channel to permit a coolant to flow past the fuel rod and pick up the heat constantly being generated within the fuel rod itself.

In this drawing fuel rods and channels are separated from other fuel rods and channels by blocks of moderator material. Enough moderating material is provided between fuel rods so that a neutron generated in the upper right-hand corner fuel rod will be slowed down sufficiently by the time it strikes an adjoining fuel rod to enable it to be captured by a fissionable atom in the adjoining rod.

Also shown in Fig. 1 is a control rod that has been partially inserted in the reactor. This rod, as already mentioned, is composed of high crossed-sectioned materials that soak up neutrons readily. It is shown inserted in the reactor in a position that enables it to soak up all neutrons in excess of those needed to maintain the chain reaction at a particular level. If the control rod were to be inserted further into the reactor it would slow down the chain reaction or even snuff it out. On the other hand, if the control rod were further withdrawn from the reactor, the rate of chain reaction would increase.

The shield and the blanket are not shown in this diagram. The shield, of course, would be wrapped completely around the reactor as shown, and would be thick enough to prevent any escape of radiation from the reactor core itself. Breeder elements also might be placed around the outside of the reactor core (in an area known as a *blanket*) to take advantage of neutrons which have escaped from the chain reaction. It should be pointed out that breeder elements can also be used within the core of the reactor itself and conceivably might substitute for some of the fuel rods shown in the diagram.

Nuclear Fuels: Nuclear fuels can be solid or liquid, but since most power reactors considered to date primarily employ solid fuels, this discussion will be limited to solid fuel elements. As there are only three well known fissionable materials, namely U^{235}, U^{233}, and plutonium, a fuel element must have at least one of these materials in it. Fissionable material can be present in simple metallic form, such as a simple bar of uranium or plutonium, or in an alloy with another metal such as aluminum or zirconium. Aluminum and zirconium can be used as alloying or diluting materials because of their relatively low

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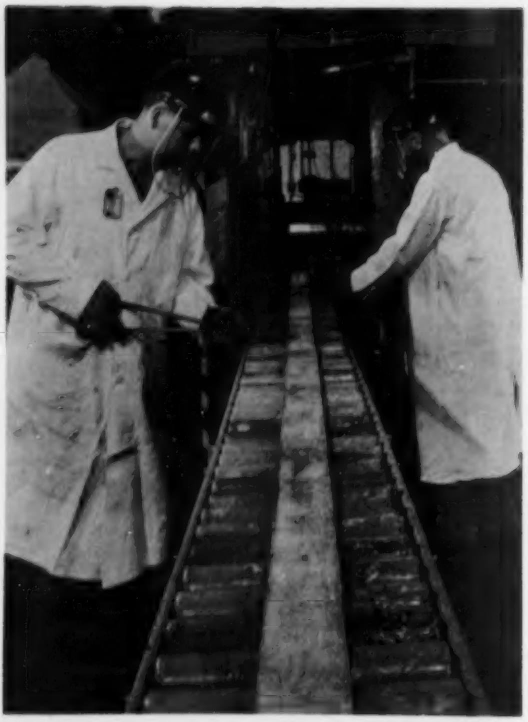


ABOVE: Rolling of uranium plate prior to cutting into fuel element strips. BELOW: Semiautomatic equipment used in the production cladding of fuels.

cross sections; hence their presence in a fuel element will not seriously interfere with the maintenance of the chain reaction. In some cases the fissionable material can be used in a ceramic form such as particles of uranium oxide dispersed in a metal matrix. In each case the fissionable material is employed in a manner dictated by the need for corrosion resistance, heat conductivity, high-temperature strength, and dilution of fissionable material. It is conceivable that fully-ceramic fuels can be fabricated which can be operated at higher temperatures than most metals, but ceramics offer problems as to strength, heat conductivity, and thermal shock resistance.

Since the fuel elements of a reactor are usually the components that operate at the highest temperature and are subject to the greatest intensity of nuclear irradiation, *it is in the area of nuclear fuels that some of the greatest strides forward in nuclear power can be achieved.* To obtain a higher thermal efficiency, it is necessary to operate nuclear reactors at higher temperature. This means that one of the toughest problems and greatest challenges now facing the materials engineer is the development of new fuel forms capable of operating at extreme temperature levels.

Nuclear fuels also seem to be more subject to physical disintegration or dimensional instability than any other reactor component. Before low-cost nuclear power can be achieved, ways must be found to reduce or prevent completely the dimensional instability of nuclear fuels.

Because high-temperature operation and dimensional stability are so important to efficient reactor operation, much emphasis is being placed on development of high-temperature fuels and fuels that will remain in a reactor without distortion or disintegration for considerable lengths of time.

Reactor Coolants: A good reactor coolant must be a relatively inert material so that it will not corrode the fuel, the fuel channel, or any other piping or duct systems through which it passes. In many cases water has been found adequate for this purpose. However, where reactor designs call for low-pressure, high-temperature coolants, liquid sodium (or a liquid sodium-potassium mixture called *NaK*) has been used. In the case of gas-cooled reactors, helium, carbon dioxide, and air are effective coolants.

Moderator materials are limited to light-weight elements. The reason for this may not be readily apparent. The purpose of a moderator is to slow down the speed of a neutron so that it can be more readily captured by a fissionable atom. Now neutrons, although they have no electric charge, have a mass in the atomic scale of approximately 1. Neutrons will fly around the inside of a reactor until they are captured by another element. However, it is possible for a neutron to strike an atomic nucleus and bounce off this nucleus without being captured. If such a neutron-atomic nucleus collision occurs, the neutron will impart some of its momentum to the struck nucleus, and as a result the neutron will be slowed down. If the atomic nucleus is of low atomic weight, it will slow the neutron down to a greater extent than if the neutron had collided with a large atomic nucleus.

Consider, for example, a billiard ball in motion striking a billiard ball at rest. In this case, where

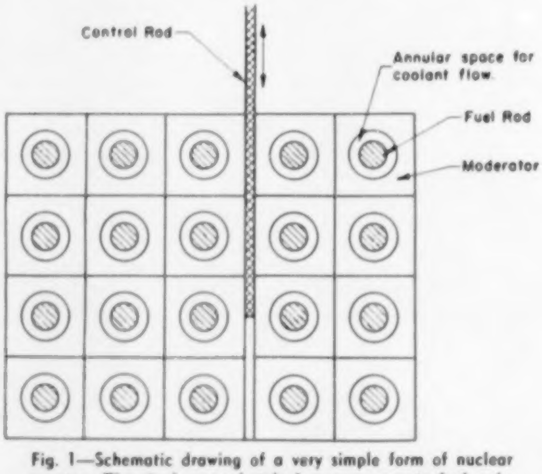


Fig. 1—Schematic drawing of a very simple form of nuclear reactor. The single cross-hatched area represents fuel rods, which are placed at regular intervals in a larger opening known as the coolant.

the masses of the two balls are essentially equal, after the collision both balls will be in motion and the impinging ball will have been slowed considerably. On the other hand, if a moving billiard ball were to strike, instead, a large bowling ball at rest, the bowling ball would hardly move, and the billiard ball would bounce off at almost the same speed at which it had struck. Thus, when neutrons are to be slowed down, it is desirable that they bounce off as many atomic nuclei close in mass to a neutron as possible. Hydrogen, which has an atomic nucleus of mass 1 (virtually the same mass as a neutron), is almost the ideal moderator. Water, which contains a high concentration of hydrogen, is frequently used as a moderator but has many limitations in high-temperature reactors. Hence more suitable light-weight materials must be used. Helium, the second lightest element known, cannot be used; its gaseous nature will not permit enough atoms of helium to be packed in a small enough volume to be effective. Lithium too, which at first glance looks as though it might make a good moderator material, must be ruled out because it has a relatively high neutron cross section. This essentially leaves beryllium and carbon. Carbon has been used extensively (in the form of graphite) in a number of reactors both here and abroad, whereas beryllium, being considerably more expensive, has found only limited use to date.

Control Rods: The aluminum, stainless steel, or other structural materials used for control rods are usually alloyed with boron, cadmium, or hafnium, which are among those materials having the greatest affinity for neutrons. The control materials can be used in metallic form or can be dispersed in a metallic matrix in the form of their oxides or carbides. The important thing is that sufficient quantity of these control elements be present in the rod to perform an effective job of soaking up neutrons.

Reactor Shields: Reactor shields usually have two jobs to do. The first is to prevent stray neutrons from escaping from the reactor. The second is to intercept intense gamma radiation emanating from the reactor core. A good neutron-absorbing material placed in the inner portion of the shield will effectively soak up neutrons. Thus boron, hafnium, or other neutron absorbers are often found in the inner portion of the shield. Unfortunately, however, nothing stops gamma rays except matter—any kind of matter—and the denser the better. Thus iron, lead, concrete, and even earth and water are used to shield against gamma rays. For power reactors, where space is not particularly at a premium, lower-cost and usually bulkier shields can be employed. In a submarine or aircraft, where space is important, meticulous care must be taken in selecting shielding materials so that minimum shield volume and weight can be achieved.

Breeder Elements: The fertile materials making up breeder elements are those which can be converted, by neutron absorption, into fissionable materials. At present there are two such materials, thorium and U^{238}. Breeder elements are normally made of rods, plates, or other geometric forms com-

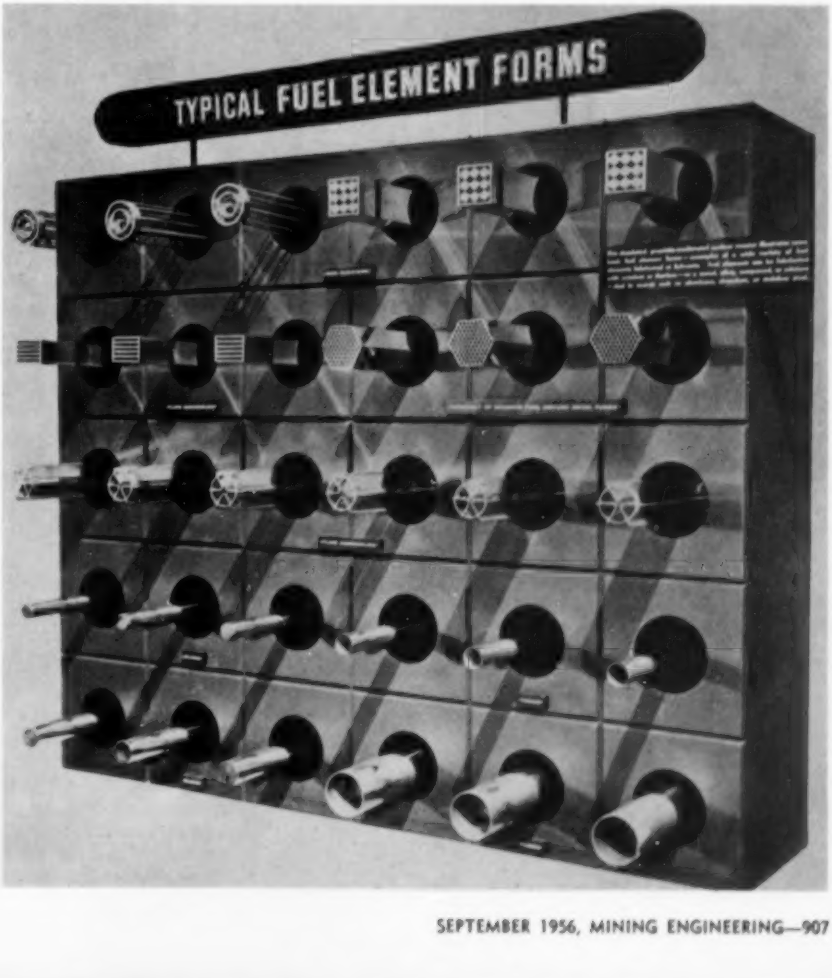
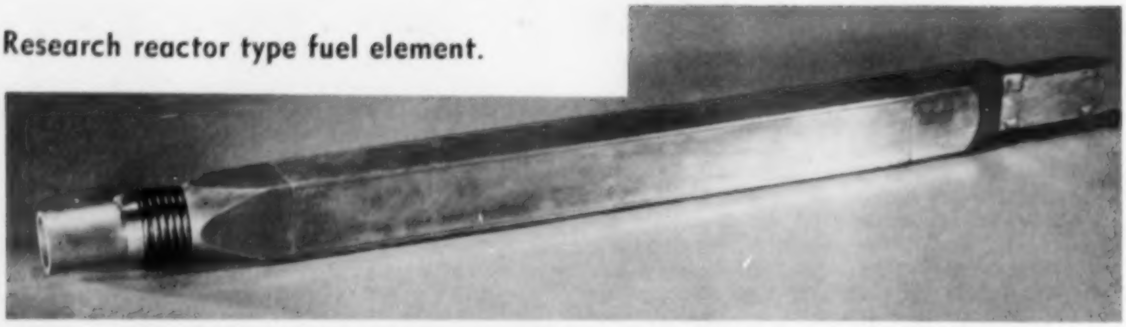


Fig. 2—Fuel element forms comprising tubular shapes, rod forms, plate configuration of several types, squirrel cage assemblies of thin rods, and wafer forms. It is a problem to maintain these shapes in a reactor under extreme temperature variation and intense nuclear radiation.

Research reactor type fuel element.



prising thorium or U[illegible] metals. In the case of fuel elements, alloys, or mixtures of these metals, they are composed of other inert materials such as aluminum or zirconium. Indeed, most of the shapes included in fuel elements can also be considered for breeder elements.

Ten years ago many materials used in reactor components would have been considered semiprecious or rare. Since then so much has been determined about the sources, ore treatments, and manufacturing techniques for these materials that a detailed discussion of raw material sources and fabrication techniques cannot be undertaken here. It is sufficient to say that finding materials is a worldwide undertaking. Uranium is mined in South Africa, the Belgian Congo, Canada, the Colorado Plateau, and Australia; thorium in the U. S., Brazil, and India; beryllium in Brazil; and zirconium in Australia, India, Africa, and Brazil. These materials can be extracted, reduced, and fabricated by well known basic techniques, but in almost all cases steps must be included in the preparation of these reactor materials to achieve a high degree of purity. The presence of many impurities detracts from the nuclear quality of the end product, and often affects the fabrication properties of these materials.

Future Essentials in Materials Development

1) Nuclear fuels must be developed which will operate at higher temperatures, over wider temperature fluctuations, and for longer burn-ups than now possible.

2) Cost of certain important reactor materials, such as zirconium, beryllium, and heavy water, must be materially reduced.

3) New materials capable of withstanding severe corrosion conditions and high temperature ranges must be developed and put to use in reactors.

4) New forms of moderating materials must be developed so that moderation of neutron velocities can be achieved in smaller volumes than are now possible.

5) New and better shielding aggregates must be developed, especially for use in package power and mobile reactors, so that this type of reactor can become lighter in weight and more readily usable in confined spaces.

6) A low-cost fuel recovery process must be developed and put in production.

Fabrication techniques, as in most other metals, include casting, extrusion, rolling, wire drawing, and swaging. For many of these materials, and for many components, powder metallurgy techniques play an important role. Although these materials often can be fabricated into a number of shapes by a wide variety of techniques, *it is becoming increasingly clear that the greatest care must be exercised in selection of fabrication techniques for fuels and other components if higher reactor temperatures, longer fuel burn-ups, and longer life of all components in reactors are to be achieved.*

Also of critical importance in a reactor is the interrelationship of one material to another. For example, most fuel elements must be covered with a protective layer of material known as cladding. This cladding is used to protect the fuel core from the corrosive action of the coolant. At the same time the cladding prevents highly radioactive fission products, generated during the chain reaction, from leaving the fuel and entering the coolant stream. This cladding material, therefore, must be compatible with both the coolant and the fuel element itself. Since heat is constantly generated in the fuel and must pass through this cladding to the coolant, the cladding usually must be well bonded to the fuel.

Fuel Economics

There is just one other point which is of paramount importance to the economics of nuclear power and can be considered a materials problem. After a fuel element has been discharged from a reactor, most of the original fissionable material present in that fuel has not been burned. It becomes desirable, therefore, to reprocess the fuel element to recover the unburned fissionable material, and at the same time remove from it the intensely radioactive fission products. At the present time, fuel recovery operations are performed only in government-owned recovery plants, although several industrial concerns are seriously considering the construction of privately owned fuel recovery plants. To be most effective, however, any new plant built for reprocessing of fuels must operate at considerably lower cost than those now in operation.

In conclusion, it should be stressed again that the problem of materials now stands between us and practical nuclear power. This is true in the initial preparation and fabrication of fuels and other reactor components, as well as in fuel recovery.

Underground Haulage In Metal Mines

by S. H. Ash

Diesel locomotives, trucks, bulldozers, and other diesel-powered equipment are fast proving their superiority for mine transportation purposes.

MORE than 100 minerals are mined and processed in the U. S. Management and labor have negotiated wage-scale agreements that have balanced wages and affected cost of labor in such a manner that comparisons can be made of transportation costs. Transportation of materials underground has become of vital importance.[1-6]

This report describes underground haulage methods and equipment, presents cost analyses, and discusses future plans for underground transportation in metal mines. It does not cover hoisting in shafts or slopes by cage, skip, or cars. Advancements have been made by the metal mining industry in lowering transportation costs in several mines, making it possible to mine orebodies or portions of orebodies not considered economically recoverable a few years ago.[7,8] Numerous reports have been written on transportation at metal mines; this report covers recent haulage at some representative mines throughout the U. S. The term *metal mine* is used to include all noncoal mines from which up-to-date information was obtainable.

The best haulage equipment is subject to breakdowns and accidents; but unless the rolling equipment, track, and signal systems are kept in good repair and are operated systematically, these breakdowns and accidents are likely to be frequent, destructive, and more costly than are necessary.[10] Rail haulage crews using dependable rolling stock can move trips safely over grades low enough to be traveled without loss of control; this applies particularly if the track is straight and well maintained. Few accidents occur on main haulage lines if visibility and clearance are good and clear track is assured. One-way traffic underground is a recent development contributing to reduction of accidents and increased efficiency in mine haulage (Kelly mine, Anaconda Co., Butte, Mont., and Climax mine, Climax Molybdenum Co., Climax, Colo.).[9]

Locomotives: Six types of mine locomotive used in recent years are trolley, storage battery, combination trolley and storage battery, diesel, compressed air, and gasoline.

Electric haulage has been displaced by compressed air locomotives, which have been used successfully in certain instances, especially on dirty and wet tracks and steep grades.[11] Maintenance cost is high, and operating efficiency, from a power standpoint, is low. Compressed air locomotives operate under self-contained power, and the absence of bare elec-

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trically charged wires removes the hazards of fire and electric shocks. An expensive multistage compressor installation is required, however, and high-pressure air lines to the charging station are costly; stations must be installed at advantageous points to which locomotives must return for frequent charging. In some mines it is stated that the exhaust air from such locomotives improves the ventilation, but this effect is often offset by clouds of vapor caused by the exhaust, fogging the drifts and interfering seriously with vision. Power cost usually averages four times that for electric locomotives, which also have better starting and speed control. Recent experiments have been made with low-pressure engines (90 psi), but their use to date has been too restricted to permit drawing conclusions.

Gasoline locomotives have been used to a slight extent underground in metal and nonmetallic mines. They are not allowed in mines in most states because of the danger of carbon monoxide from exhaust gases and fire from the gasoline. The Federal Bureau of Mines is officially on record as opposing the use of gasoline locomotives in underground mines.[9, 10, 12]

Storage battery locomotives have displaced trolley locomotives in both large and small mines and in secondary haulage in larger mines owing to their more flexible operation and the ease with which they can be moved from one level to another.[9, 14] They have special value in timbered drifts that crush badly and where high maintenance cost of trolley wires and the danger of fire virtually prohibit use of trolley locomotives. They are also safer in operation because of their lower voltage and slower speed and the absence of bare trolley wires.[9]

In storage battery locomotives of the 1½-ton type the operator's seat is constructed so that it folds over the battery, making it possible to transfer the locomotive easily from one level to another on the deck of an ordinary mine cage. Such locomotives are used mainly for transporting materials in sublevels and for hauling muck from development headings. They are also used to some extent as gathering locomotives. This type of locomotive haulage is rapidly replacing hand tramming.

In eliminating the use of charged electric wire, storage battery locomotives offer a great advantage, but there is danger of burns from ignition of gas when the battery is charging and burns from electrolyte. Battery trays should be well insulated from the boxes.[9]

Used extensively in Michigan copper mines and to some extent in Michigan iron mines, storage locomotives have been found very satisfactory in service and from an operating standpoint are as economical as trolley locomotives. In Montana some mines have replaced trolley locomotives with storage battery locomotives.

In terms of efficiency both trolley and storage battery locomotives have their proper place.[14] For large capacity and long hauls trolley locomotives are favored for efficiency but are unsafe. Storage battery locomotives for this type of service are costly and require large ampere-hour capacity. Unless the ore or rock comes in surges so that there are slack times during the working period when batteries can be put on charge, or a long enough interval between haulage shifts for this purpose, the batteries may run too low and be discharged below the desirable or safe limit. For heavy service, two sets of batteries are usually provided for each locomotive, and one set is charged while the other is in use.

Although storage battery locomotives must return at definite intervals to a charging station, they are very flexible up to the limit of their ampere-hour capacity. Battery locomotives have a higher first cost than trolley locomotives of the same capacity, requiring installation of charging facilities and expert maintenance.

Diesel engines are also replacing both types of electric locomotives as well as internal combustion engines burning gasoline and butane fuels in underground mines.[2, 5, 9, 12, 16, 20–24]

Introduction of the diesel locomotive has resulted in more careful track laying, fewer derailments, fewer haulage accidents, and lower haulage costs. Where roadways are through gobs and wooden-timbered sections, diesels are definitely safer than electric trolley wire locomotives, and much more flexible.[12, 20, 24] Experience shows that the diesel locomotive is not unsafe if good track, good maintenance, and good ventilation are provided. Safe operation of diesel equipment can be assured by the following precautions:[5, 9, 12, 13, 17, 22, 25, 26]

1) Adequate ventilation where engines operate to dilute the toxic constituents of the exhaust (75 cfm per rated horsepower is a recommended safe minimum) and an atmosphere having a carbon monoxide concentration not exceeding 20 ppm.

2) Good maintenance at all times.

3) Provision of a scrubber to cool exhaust gases and remove particulate matter.

4) Use of engines of the indirect-injection type underground. (Extensive testing has shown that these engines produce less oxides of nitrogen in the exhaust.)

Hand tramming as the principal method of haulage is today largely confined to small mines or parts of mines having a small output. Hand tramming has been largely replaced by storage battery locomotives of the tramming type, which can be run on a cage and transferred quickly from level to level.

Animals are occasionally used to return empty cars to the work faces and to gather loaded cars.

Trackless Haulage: In many mines methods and systems have been redesigned to use trackless equipment of all types.[2, 22, 27–29, 30–32] Trackless equipment is especially adaptable to flat-lying orebodies 12 ft thick or more. Drills are mounted on jumbos; some are mounted on caterpillar-tread tractors, and others on pneumatic tires. Shovel loaders are mounted on caterpillar treads and pneumatic tires. In the Alabama iron mines shovel loaders on caterpillar treads and shuttle cars with pneumatic tires have virtually displaced the scraper-and-slide method of loading and transporting broken ore from the breast to central main haulage. This type of equipment has been used successfully on gradients up to 18°. The Ishkooda No. 11 mine,[9] operated by the Tennessee Coal & Iron Div. of the U. S. Steel Corp., Fairfield, Ala., reportedly was the first iron mine in the world to use a mobile loader discharging into shuttle cars. Increasing use of shuttle cars is reflected in the 22 shuttle cars issued approvals by the U. S. Bureau of Mines during 1955.

Shuttle cars require less headroom than trucks. Operated by storage batteries, cable-reel trailing cables, or diesel engines, they are as safe and efficient as other pieces of trackless haulage equipment.[1, 9, 22] If they are powered by storage batteries, there are the ever present hazards incident to trans-

Transporting of material in metal mines generally comprises hoisting and haulage. Hauling in underground metal mines may be by rope, locomotives and cars, trucks, shuttle cars, and hand tramming.

ferring and charging batteries, but the danger is no greater than for storage battery locomotives. If they are operated by cable reel, trailing cables inadequately maintained present a shock hazard.

Shuttle cars are used where tracks cannot be maintained because of bad bottom. At the underground mines of Reynolds Mining Corp., Bauxite, Ark., the floor underneath the bauxite consists of various types of clays, bauxitic clay or a very low grade bauxite, altered syenite clay that is rather firm, and a red mottled Midway clay. When saturated with water the red mottled clay becomes plastic, about the same consistency as a child's modeling clay. This material will squeeze and, if too much weight is imposed on the ore, will completely fill the drifts. Motion varies in this from no movement in the drifts to as much as 4 to 5 in. vertically in 24 hr. As none of these clays will support shuttle cars, it is necessary to floor all drifts with 4-in. hardwood planking fastened to sleepers.[40, 41]

Studies were made of shuttle car units in operation to determine their merits and disadvantages for haulage.[7, 37, 42] Because available methods of analyses did not rate machines properly, S. H. Ash developed a method of interpretation using results from field studies to provide an accurate basis for rating shuttle cars and loading machines with which they work.[37]

Trucks powered with gasoline, butane, and diesel engines are used extensively as haulage units in underground limestone mines and sandstone mines in the central states and in the Tri-State lead and zinc district.[8, 9, 15, 18, 19, 22, 30, 43, 44] The mines are in a flat or nearly flat formation, where it is possible to build roads without excessive grades. Mine workings generally range from 12 to 50 ft. Overlying strata are supported by pillars, and usually there are several openings to the surface, which provide natural ventilation.

Transportation frequently is by means of diesel-powered trucks operated either as tractor-trailer units or trucks with integral bodies.

Trackless haulage is best adapted to large open workings and those in which the roof strata are supported by pillars or rock bolts. If workings are timbered with wooden supports, posts and stulls are likely to be dislodged by equipment striking them, causing rock falls. Rock bolting in underground mines has made it possible to operate shuttle cars and trucks.

Conveyor Haulage: Conveyors are used extensively for transporting ore and waste in opencut mines. They are also employed less widely in underground mines.[43, 45-48] A number of underground belt installations are available for intermediate and main haulage in metal and nonmetallic mines. Rayner describes a conveyor system in an underground mine that conveys and elevates ore in a 17° inclined shaft from the 1500-ft level to the concentrator on the surface.[49]

Belt conveyor main haulage is used in several mines in the Lake Superior district. Gathering methods for transporting ore to the belt vary from mine to mine and even in the same mine. Shaker conveyors, slushing methods, and shuttle cars are now in use. To be economical, belt conveyors require a critical uniform feed, with the belt operating at near capacity.

Interesting developments are the use of extensible belt conveyors and the *bridge* or *piggyback* conveyors. These devices promise to be of material aid in handling the production of continuous miners.

One of the difficulties in conventional belt-conveying practice is adherence of particles of material to the carrying surface of the belt.[9, 49] When sticky materials are transported this often causes buildup of material on the return idlers, which may result in difficulty in training the belt.[50]

Although there are many devices for cleaning the surface of belt conveyors, even the best of these has not been entirely effective, and most require troublesome maintenance. One solution may be to twist the belt through 180° so that the clean surface is carried on the return idlers. The belt is inverted again just before the return pulley to restore it to its normal position for the forward run. The method has been successfully used to stockpile more than 1 million tons of ore in Michigan. Here it has been found that, for successful use, all belts should have vulcanized joints. Water sprayed on the ore-carrying side of the belt as it is twisted underneath to the return idlers lessens the fine spill under the beltline. Experiments in Great Britain and a few

tests in the U. S. indicate that this method is feasible and has certain advantages.[illegible]

Signal and Communication Systems: Transportation on many haulage levels now is frequently controlled by a dispatcher who transmits messages to motormen over a trolley mine telephone system. Intercommunication among motor operators is possible; thus collisions and delays are prevented.[illegible]

To increase efficiency and safety in haulage, several large mining companies have installed dispatcher systems with voice signals relayed over radio communication equipment on each locomotive and at other strategic places. Voice communication on a two-way basis has done much to lower costs and to relieve congestion and hazards in transporting ore underground.[illegible]

A system installed by the Tennessee Coal & Iron Div. of the U. S. Steel Corp. in Alabama consists of frequency modulation transmitters and receivers. Units were installed in each of the mainline locomotives; one each in a dispatcher's office at rotary dumps, the underground maintenance shop, and motor pit, and one on a material-handling locomotive. Units operate on 100-kc frequency modulation; power is from the trolley wire. Current passes through a voltage divider, which gives 120 v to the transmitter and 35 v to the receiver. This system is operated to augment and not replace block signal systems.[illegible]

The dispatcher should have absolute control over the movement of trains. He also clears and relays messages that come from all parts of the mine by the locomotive-mounted units. Supervision can thus be applied more effectively; calls for materials can be relayed to surface; and trains can be efficiently routed. Such equipment can also greatly expedite removal of men from a mine in case of emergency.

Some block signals are operated automatically; others are manually made and broken by locomotive operators. Even in the smallest mine, locomotives can be equipped with headlights and gongs and trips with tail lights and warning devices.

As an emergency signal system to warn all employes in the least possible time, a stench-warning system in the compressed-air line and ventilation currents is unequaled.

Ore-Handling Systems: Ore handling, other than transportation underground, generally consists of loading, dumping, and storing. Important changes have been made in methods of handling ore at many mines, and transportation of products from large mines is rapidly becoming completely mechanized, either as a single operation or a series of such steps. Instead of repeated handling of ore and waste at various levels, systems of raises and pockets are driven to carry the ore or waste to centralized stations from which they can be drawn as required. To minimize having the ore or waste hanging up at inaccessible places, the broken material from the stopes may be passed through a grizzly before entering the ore or waste pass system.

Departures from the branch raise system are for the purpose of removing the hazards, delays, and costs evident after a few years' use of the system in various districts. In the Climax mine in Colorado and the Montreal mine in Wisconsin, slusher drifts and slushers have replaced chutes and many of the raises. Similar changes have been adopted in other iron mines of the district. In the mines of the Tennessee Copper Co. a slusher system replaced the grizzly-loading system.[illegible]

General Description, Cost Analysis, and Future Planning at Typical Mining Layouts

Mining Plant A

Mining plant A, a low grade zinc-lead mine in the Pacific Northwest, produces about 2000 tpd, or 40,000 to 43,000 tons a month, by working two shifts for a five-day week. The mill concentrates 1600 tons of ore each day on a three-shift basis and operates six days a week. The mill feed, as mined at present, has a combined metal content of 3 to 3½ pct, consisting of 1½ to 2 pct zinc and 1½ pct lead. Of the 160 to 175 men employed, 115 work underground. The average output per manshift for all underground employes is about 17.4 tons.

Ore exploitation and development are mainly from an inclined shaft 3830 ft long. The shaft collar at the portal is at altitude 2180 ft and the shaft bottom at 1300 ft. The upper 1450-ft section of the main incline shaft, the middle 1180-ft section, and the bottom 1200-ft section dip 17°, 10°, and 12°, respectively.

The 2000, 1900, 1800, 1700, and 1450 levels are off the main incline shaft at 100-ft intervals, vertically, except the 1450 level, which has a vertical interval of 250 ft from the level above. Access to the 2200 level is by means of an adit. The 1700 level is the lowest producing level.

The replacement-type ore deposits, which are in limestone and generally very irregular, are being mined by open stopes. Large open stopes are employed in which 98 pct of the ore is recovered. The remaining 2 pct consists of ore and waste and is left in pillars for ground support. Roof support is aided by arching the back (roof) of the open stopes. Careful scaling of the backs and frequent inspections in stopes and haulageways are made to insure safety of the workmen.

Haulage Equipment: All the broken ore from the stopes on each level is first crushed to −1 in. before the ore is fed to the conveyor belt in the incline shaft to be conveyed to the ore bins at the mill.

The ore is transported in the incline shaft at a rate of 400 tons per hr by a conveyor belt 30 in. wide. The endless-belt conveyor system is in three sections, the upper 1450 ft long and the lower sections each about 1200 ft long. Ore is conveyed from the incline shaft to the ore bins at the concentration plant by a similar belt conveyor.

Track and slusher types of transportation were discontinued in March 1952, and trackless diesel-powered equipment is now used for drilling, mucking (loading), and transportation.

Ten-ton Dart diesel trucks transport the ore from the stopes to draw chutes or mill ore bins. These trucks are powered by Cummins HR-4, 4-cylinder, 4-cycle, indirect-injection diesel engines with 5⅛-in.

bore and 6-in. stroke. They develop 110 hp under full load at 1800 rpm.

Tracto-Shovels load the diesel-powered trucks. The Allis-Chalmers HD-5G Tracto-Shovels are powered by General Motors 2-cylinder, 2-cycle, direct-injection diesel engines; these have a 4¼-in. bore and a 5-in. stroke and develop 40.26 hp at drawbar and 50.25 hp at belt.

Eimco-Caterpillar D-4 tractor-combination loaders and drill jumbos are employed; these are powered by Caterpillar diesel 4-cylinder, 4-cycle, indirect-injection engines having a 4½-in. bore and a 5½-in. stroke and develop 43 hp at drawbar and 48 hp at belt.

All underground diesel equipment is provided with electric or compressed air starters and exhaust gas scrubbers. The exhaust gas scrubbers are made locally; they are installed at the rear end of the equipment several feet back of the operator's seat. The scrubbers contain 29 gal of water when filled. Coarse calcite or limestone is used to neutralize acid in the scrubbers, which are drained and filled with water each shift and cleaned periodically.

An adequate volume of air is coursed mechanically through the mine by large-capacity fans for diluting and removing toxic and harmful constituents of the exhaust gases. Auxiliary blower fans of 16,000 cfm at rated capacity with 3-in. water-gage resistance and 30-in. diam tubing are used to ventilate *dead ends* in the mine. Daily tests of the mine air in the working places are made with a colorimetric carbon monoxide indicator. A record is kept in a book for examination by the State metal mine inspector and other interested persons. The State mine inspector also tests for oxides of nitrogen with a portable indicator when making periodic safety inspections of the mine to insure that requirements for healthful working conditions are being complied with. Check air samples are also collected from time to time in vacuum bottles by USBM engineers to determine the adequacy of the ventilating system and maintenance of the equipment.

The foundation of any underground transportation system is its roadbed, whether transportation is by rail, shuttle car, truck, slushers, or conveyors. The feasibility of maintaining a good roadbed is often the controlling factor in selection of transporting equipment. Cost of transportation depends on so many variables that each mine presents its own problem and the most economical system can be determined only by the solution of many problems.[7,27,41] Examples of transporting facilities and costs at typical plants illustrate conditions that have counterparts elsewhere.

Storage battery locomotives are employed in the operating haulage levels for transporting ore from the draw chutes to the main inclined shaft ore pockets.

Cost Analysis: Although transporting costs were not available, the cost for a ton of ore taken from the annual report of mine A for the year 1954 is as shown in Table I.

Table I. Costs in Dollars per Ton, Mine A, for 1954

Mining	1.743
Milling	0.742
Other	0.292
Subtotal	2.777
Administrative, general expenses	0.141
Taxes	0.136
Total	3.054

Mining Plant B

Mining plant B is a chrome mine that produced 1000 tons of ore daily. The ore contains 19 to 21 pct chromic oxide (Cr_2O_3), which is concentrated at a gravity-type mill situated at the lower camp. The concentrate from the mill is hauled by autotruck and stored at a government stockpile half a mile from the mill. Of the 226 men employed, 146 work underground. Average output per manshift for all underground employes is 7 tons.

The mine is opened by six levels or adits, known as Nos. 1A, 1, 2, 3, 4, and 5, situated at altitudes 7820, 7670, 7525, 7360, 7220, and 7060 ft, respectively. Ore occurs in two veins, 400 ft apart and nearly parallel. The veins strike 60° northeast and dip 50° to 55° to the northwest. One vein is 7 to 8 ft wide and the other 4 to 5 ft wide. Ore is continuous in the vein structures, and minor faults have not proved difficult in following continuous stoping. Generally, the granitoidal wall rock structure is such that shrinkage stoping can be followed in both veins without leaving pillars or stulls for additional wall support.

Haulage Equipment: Mechanical haulage is used in all levels. The grade, in favor of the loaded trains, is about 0.25 pct. Track gage is 24 in. and the rail weight 30 lb.

Goodman 3-ton and 5-ton storage battery locomotives, equipped with brakes, headlights, and warning devices, are used to haul ore and waste in the 1, 2, 3, and 4 levels. Diesel locomotives, manufactured by the Goodman Mfg. Co., are used in the 2, 3, and 5 levels. A 4-ton diesel locomotive is in use on the No. 2 level, a 4-ton on No. 3 level, and a 6-ton on No. 5 level. All diesel locomotives are equipped with scrubbers of 36-gal capacity. Scrubbers are drained each 8-hr shift and filled with water to which three tablespoons of hydroquinone are added. Each diesel locomotive is equipped with fluid drive, 12-v acid-storage batteries, two headlights, electric starter, signal horn, and mechanical brakes. The company safety engineer makes periodic tests of the mine atmosphere with a colorimetric carbon monoxide indicator to determine whether the locomotives are functioning properly and whether ventilation in the haulageways is adequate. Enough air is coursed mechanically in all operating levels by means of fans to insure healthful working conditions for all employes. The main fan exhausts 39,000 cfm from the mine and two auxiliary fans deliver 10,000 cfm and provide positive ventilation to the face workings of the operating levels.

Granby-type side dump steel cars are used exclusively. The cars are 4.2 ft wide with the side dump (fifth) wheel extending 0.55 ft beyond the body; those on the upper levels have a capacity of 2.5 tons, those on No. 5 main haulage a capacity of 4.2 tons. Four to ten cars are hauled in each train.

Cost Analysis: Specifications of the 4-ton and

Table II. Specifications for Diesel Locomotives, Mine B

Item	Four-Ton	Six-Ton
Type, General Motors	2-cycle, direct-injection	2-cycle, direct-injection
Cylinders, no.	2-in-line	3-in-line
Bore diameter	4¼ in.	4¼ in.
Stroke	5 in.	5 in.
Total displacement	142 cu in.	213 cu in.
Continuous horsepower	45	67
Revolutions per min without fan	1600	1600
Compression ratio	16:1	16:1
Compression pressure at 500 rpm	418 psi	418 psi
Fluid drive	Yes	Yes
Scrubber capacity	36 gal	36 gal
Number of Locomotives in Use:	**Two Four-Ton**	**One Six-Ton**
Initial costs	$10,245 each	$12,245 each
Date of installation	August 1953	June 1953
Horsepower of each	45	67
Weight of Granby type, empty	6000 lb	7400 lb
Weight of average loaded car	11,600 lb	15,800 lb
Average number of cars per trip	4	10
Average distance traveled	Variable	1500 ft
Average number of round trips	Variable	22
Average train speeds	7½ mph	7½ mph
Average daily fuel consumption	5 gal @ 16.4¢	11½ gal @ 16.4¢
Repair and maintenance costs	omitted	omitted
Tons handled daily	150 to 450	873

6-ton diesel locomotives are given in Table II. The diesels are equipped with such items as torque converters, torque converter coolers, and built-in exhaust scrubbers.

Battery locomotives (initial cost $10,000 each) are used in development headings or for hauling supplies, but very seldom for ore haulage. Cost comparisons cannot be made at this time, therefore, between diesels and battery locomotives.

The mobility of diesels is outstanding, but operating time has been of too short duration to give reliable figures on costs.

Mining Plant C

Mining plant C consists of two large lead-zinc mines, one of which is listed as Section 1 and the other as Section 2.

Haulage System: The following tabulations summarize the main features of the transporting systems. Electric-powered equipment consists entirely of trolley and storage battery units. A mainline haulage tunnel serves both sections, Tables III, V.

For Section 1, ore and waste are trammed an average distance of 22,261 ft to surface; the most remote distance one way to surface is 23,650 ft. For Section 2, average distance to surface is 11,322 ft and most remote distance 14,200 ft.

All underground haulage is by rail: 30-lb rail of 18-in. or 24-in. track gage, ½ to 1 pct grade, and 45 to 100-ft radius curve; haulage clearance, 6 to 7 ft; up to 12 cars per train.

Storage battery locomotives are utilized for transportation in all haulage passageways except in the mainline tunnel. A summary of that equipment and other pertinent detail is presented in Table VI.

Table IV presents data concerning the types of mine cars transporting both ore and waste.

The total distance traveled by all mainline and underground haulage level locomotives (round trip) averages 152 miles in a 24-hr period (2 shifts). There are 47 miles of underground trackage.

Cost Analysis: Table VII summarizes average overall costs per ton-mile, excluding overhead and depreciation, for ten months of 1955.

Battery replacement cost for ten months of 1955 is $0.08 per dry ton of ore. Electric power cost for tramming for first ten months of 1955 is $0.12 per dry ton of ore.

Table III. Data for Mainline Haulage Tunnel Serving Sections 1 and 2 of Plant C

Cross section 9x10 ft in clear, 8x9 ft in timber.
Rail gage, 36 in.; weight, 60 lb.
Curves, 400 to 1000-ft radius.
Trolley, 550 v, dc.
Traffic control system, automatic standard railroad block system.
Ground support: sections are concreted, timbered, roof-bolted, and untimbered.
MSA mine phones used on all mainline locomotives and jeeps.
10 cars per trip, 12 tons per car.

Table IV. Ore and Waste Cars, Mine C

	Type	Track Gage, In.	Size, Cu Ft	Capacity, Tons
Section 1	Rocker bottom	18 and 24	39	2
	Side dump	24	39	2
	Gable bottom	18	27	1.5
	End dump	18	19	1
Section 2	Side dump	24	39	2

Table V. Mainline Haulage Equipment for Sections 1 and 2 of Plant C

Mainline Haulage Locomotives (Enclosed Cab):
Make: Jeffrey Manufacturing Co.
Wheel gage: 36 in.
Brakes: Westinghouse
Horsepower: 250
Weight: 40,000 lb
Speed: 15 mph
Motors: two 550-v (dc)
Wheel diameter: 36 in.
Couplers: automatic (Willison)
Compressor motor: 10 hp
Compressor: 30 cu ft capacity
80 lb pressure on brakes, 150 lb pressure on dump line
Communication: MSA mine phone

Mainline Mine Jeeps (Small-Type Service Locomotives for Personnel):
Make: Lee-Norse
Weight: 2 tons
Brakes: hand and foot type
Wheel diameter: 16 in.
Passenger capacity: 12
Motor horsepower: 3
Speed: 11.4 mph
Communication: MSA mine phone
Couplers: automatic (Willison)

Mainline Ore and Waste Cars:
Make: Baldwin-Lima-Hamilton Co.
Dump: automatic air side dump
Brakes: Westinghouse air brakes
Capacity: 7 cu yds
Wheels: 18-in. diam (8 wheels to a car)
Couplers: automatic couplers (Willison)

Converted Mainline Ore and Waste Cars:
Gage: converted to 36 in. from 24 in.
Capacity: 4 cu yd
Wheel diameter: 14 in. (8 wheels to a car)
Dump: hand operated (gable bottom side dump)
Brakes: none

Mainline Man-Cars:
Make: C. S. Card Mfg. Co.
Type: Enclosed, all steel (enter on one side)
Capacity: 30 men (4 to 6-man compartments and 2 to 3-man compartments)
Brakes: air brakes and emergency hand-operated
Wheel diameter: 12 in. (8 wheels to a car)
Couplers: automatic (Willison)

Table VI. Storage Battery Equipment for Haulage Passageways, Mine C

Type of Locomotive	Track Gage, In.	Weight, Tons	Speed, Mph
Mancha Trammers	18	1.5	3.5
Mancha Mule	18	5.0	3.5
Mancha "B" Trammer	24	4.0	3.5
Westinghouse	24	4.0	3.5
G. E. (LSB)	24	5.0	3.5
Mancha Titan "A"	24	4.0	3.5
Mancha Mule Standard X	18	5.0	3.5
Mancha Titan AN	24	4.0	3.5
Mancha Titan "B"	24	2.5	3.5
Mancha Trammer M-9	24	1.5	3.5
Atlas "K"	24	3.0	3.5
Mancha Titan AN3	24	3.0	3.5
Greensburg Monitor	24	4.0	3.5
Jeffrey	24	4.0	3.5
Greensburg Cruiser	24	4.0	3.5

Table VII. Costs Per Ton-Mile, Ten-Month Period, 1955	
Operating labor	$0.17
Repair labor	$0.07
Repair supplies	$0.08
Repairs (other)	$0.01
Storage battery replacement	$0.02
Power	$0.02
Ground support	$0.01
Total	$0.38 per ton mile hauled

Mining Plant D

One of the largest and oldest mines in the U. S., mining plant D comprises several mines, some in the development stage and 12 in production continuously during 1955. Data given in this report are for the first 11 months and are based on dry tonnage.

The vein system is not steep and is amenable to trackless mining, without which mining operations would probably have been discontinued years ago.

General Description and Haulage Equipment: From a group of 12 comprising mining plant D, mines 1, 7, and 12 are selected as typical of three sets of conditions that affect haulage costs. The following description summarizes the haulage conditions of the group of mines.

Mine 1 is typical of the high-haulage cost mines. Here there are comparatively long hauls, several haulage levels, many inclined roadways, narrow ore runs, and generally poor haulage road conditions. Also, one factor having a great influence on the haulage cost is the uncertainty of ore reserves in given areas; this results in costly haulage to pick up tonnage that is erratic as to quantity and continuity. Ore must be hauled ¼ to 1½ miles in a haulage system spread throughout 240 acres. The average distance is ¾ mile. Both dump and trailer trucks are used. The dump trucks are rated at a capacity of 9 tons and the trailers at 12 tons. Generally, two dump trucks and three trailer trucks are in use. The record shows an average wet-ton load of 9.6 tons in 1955.

Mine 7 operated during 1955 under haulage conditions somewhat better than average. Ore was hauled over distances ranging from a few hundred feet to 0.9 mile. Most of the tonnage was hauled from two levels with only two major inclines between levels. Road conditions were relatively good. Also, large muck piles were available in some of the areas mined. The haulage equipment consisted of one 15-ton trailer truck, used on the longer hauls; one 6-ton low trailer truck used in areas with low headroom; and three 9-ton dump trucks. The 15-ton trailer was used on the longer hauls. The average load for mine 7 in 1955 was 10.6 tons (wet), and ore was hauled from points spread over 320 acres. Usually, two dump and one trailer truck are in use with a fourth unit used on a part-time basis.

In mine 12, the lowest haulage-cost mine in 1955, ore was hauled ranging a few hundred feet to ½ mile. The average haul was about ¼ mile from the hoisting shaft, which is centrally situated in a 160-acre tract. Haulage was entirely on one level except for minor inclines due to the dip of orebodies. Road conditions were better than average. Also, most of the tonnage came from large muck piles. Haulage equipment consisted of one 7-ton dump truck, three 10-ton trailer trucks, and two 12-ton trailer trucks. Generally five of these units were used in a day's operation. The average load in 1955 was 9.6 tons.

Cost Analysis: Table VIII lists items and haulage costs at mine plant D.

As indicated by the average tons per load in the mines described, the diesel trucks do not quite come up to their rated capacity. It should be noted that the costs in Table VIII include some miscellaneous haulage expense other than actual truck cost. These figures include such expense as haulageway lighting, road-sprinkling supplies and labor, and haulage transfer hoppers. All trucks in mining plant D were equipped with exhaust scrubbers.

Mining Plant E

Plant E is one of the largest and oldest metal-mining plants in the world, mining copper ore from five different lodes. Approximately 8000 tons of ore are hoisted per day from 11 shaft mines on these five lodes. Tramming methods used in all are very much alike owing to the similarity of the lodes. Orebodies generally lie in beds 8 to 12 ft thick dipping 36° to 38° from horizontal. Inclined shafts have been sunk along the dip of the vein and normal to the strike, either in the footwall or in the vein, depending on the circumstances. At level intervals of 150 to 200 ft, drifts are run from the shaft into the vein along the footwall. Chute holes are driven up the vein at intervals of 16 to 20 ft. Overcutting connects the chutes and serves as a starting point for stoping. The ore is mined by the ribbed pillar method of retreat stoping. Two chutes serve each stope; stopes are from 30 to 48 ft wide. In one instance, open stopes with random pillars are used.

Haulage Equipment: Goodman storage battery locomotives haul the ore to the shafts where it is dumped between the rails directly into inclined skips. Six-ton two-wheel drive locomotives and 8-ton four-wheel drive locomotives are used to pull trains ranging in size from one 5-ton to six 7½-ton end-dump cars. Car sizes are standardized by mine depending on the pertinent skip capacity; however, the locomotives vary in sizes from tramming point to tramming point depending on the length of haul and the production from any given tramming point. Average length of haul is 2500 ft. A standard gage of 40 in. and a standard rail of 40 lb are used.

Table VIII. Underground Haulage Costs, Mining Plant D, 1955

Mine	Rock Tons	Labor, $	Repairs and Supplies Including Tires, $	Fuel, $	Road Building and Maintenance, $	Total per Ton, $
1	146,488	0.145	0.229 (Tires-0.104)	0.013	0.013	0.390
2	80,510	0.168	0.206	0.008	0.001	0.383
3	143,243	0.163	0.079 (Tires-0.026)	0.014	0.002	0.258
4	149,081	0.162	0.098	0.009	0.002	0.271
5	93,679	0.140	0.085	0.006	0.002	0.232
6	87,632	0.198	0.143	0.011	0.004	0.356
7	107,818	0.147	0.107	0.009	0.001	0.264
8	64,130	0.128	0.073	0.023	—	0.224
9	57,798	0.129	0.137	0.003	0.002	0.271
10	95,445	0.138	0.109	0.006	0.002	0.225
11	129,541	0.185	0.066	0.007	—	0.258
12	221,045	0.091	0.069 (Tires-0.029)	0.003	—	0.163
Total	1,376,414	0.147	0.112	0.008	0.002	0.270

Loading and Dumping Methods: In the mines where the ribbed pillar stoping method is used, cars are loaded from wooden chutes lying on the foot of the stope and extending through chute holes over the sides of the cars. To some extent ore flows by gravity. Where flat spots occur because of a roll in the vein or where the dip is not steep enough, a scraper is used to scrape the dirt into the cars. Electric or air-driven tuggers power the scrapers.

Eimco-21 loaders are used in the drifts and in the open stope mines. Where 7½-ton cars are used with the Eimco loader, an Eimco-21 conveyor is used to fill the car to capacity. Canton car transfers or switches are used to switch cars in the development headings.

Tram cars are dumped directly into the skips by means of an air cylinder that elevates one end of the car and causes the dirt to run through the swinging door on the other end.

Storage: Facilities are not provided at the shaft for storage of ore. The present system allows for only limited storage by having more trammers than are required under normal conditions, the storage facility being the extra tram cars. Under normal conditions 10 to 12 pct trammer waiting time occurs during a shift; this is necessary to guarantee a steady supply of rock for the skip if delays occur at one or more of the tramming points.

Cost Analysis: Direct labor attributed to tramming includes loading, tramming, waiting time, and car-dumping time. It does not include labor spent scraping ore from the breast to the chutes. Tramming operates on an incentive system: cars are paid for by allowing the trammer a bonus per extra car over a variable base, which depends on length of haul, car capacity, and other factors. The bonus also varies with length of haul, etc. Direct labor cost averages $0.236 per ton; this is equivalent to 50¢ per ton-mile. Fringe benefits add $0.040 per ton. Supply costs are largely the result of battery replacements. Battery life averages seven years. Maintenance includes the indirect labor of the chargeman. Power includes all costs of supplying the dc charging current; this includes rotary MG sets and their maintenance, power lines, etc. Average tramming costs are given in Table IX.

Table IX. Average Tramming Costs in Dollars per Ton, Mining Plant E

Direct labor	0.236
Supplies	0.053
Maintenance	0.040
Power	0.031
Fringe benefits	0.040
Miscellaneous	0.016
Total	0.416

As previously mentioned, no storage is provided underground. The labor cost expended in nonproductive waiting time is estimated as 20 pct; this is $0.047 per ton. Fringe benefits amount to $0.008. Cost of maintaining a capacity hoist is then $0.055 per ton. The tramming cost can also be expressed as follows:

$$\text{Loading, tramming, dumping } \$0.361 \text{ per ton} \times \frac{5280}{2500} = \$0.763 \text{ per ton-mile}$$

$$\text{Providing storage at shaft } \frac{\$0.055}{0.416} \text{ per ton}$$

Future Planning: The need for economies in transportation is a live problem. Improvements are in process or under study for diesel locomotives and underground storage pockets, and gradual transition to 6-ton or 8-ton locomotives and 7½-ton cars is planned.

Diesel locomotives are considered because less capital expenditure is required per unit. Also, a diesel has high operating availability and greatest mobility. Without extra batteries, the present 8-ton locomotives are limited to approximately 140 ton-miles per shift. It is expected that a portion of the underground haulage will be dieselized; this will not, however, replace the storage battery locomotive haulage entirely.

Underground storage has not been adopted previously because the cost of pocket installation when applied to the indefinite and relatively low tonnage per level has not been economic. As labor rates rise and economic tramming distances increase this trend is reversed. It is expected that some pockets will be justified. Advantages are increased tramming labor efficiency, increased utilization of tramming equipment, and available ore for off-shift hoisting. Disadvantages are increased capital expenditure per plat and the necessity for better fragmentation. The present method can handle a 2x3-ft chunk.

New properties or rehabilitated mines are standardized on 7½-ton cars and skips. All new locomotives purchased are either 6-ton or 8-ton units.

Mining Plant F

In mining plant F, one of the largest and most modern metal mines in the U. S., transportation must be organized to function without delays.

Mining operations are conducted on two main levels (Nos. 1 and 2) for haulage purposes. No. 1, the more extensive, is connected to higher levels by ore passes and other raises. All the ore from these higher levels is loaded into muck trains on No. 1 level through raises out of the fingers of stub slusher drifts. No. 2 level, 300 ft below, has only three slusher drifts on a connecting higher level. These drifts also lead into the fingers of stub slusher drifts.

Although the haulage system used on both levels is similar, there are some differences, which are noted in the following paragraphs.

The adits, with timber, the fringe drifts (hanging wall and footwall drifts), and the loading drifts have timbered sections. All timbered areas are top-lagged and, where necessary, side-lagged. At present concrete is replacing timber in most new areas in the loading drifts at the loading points. Manways and loading cutouts with drawholes are concreted with the drifts. The general loading drift dimensions remain about the same .

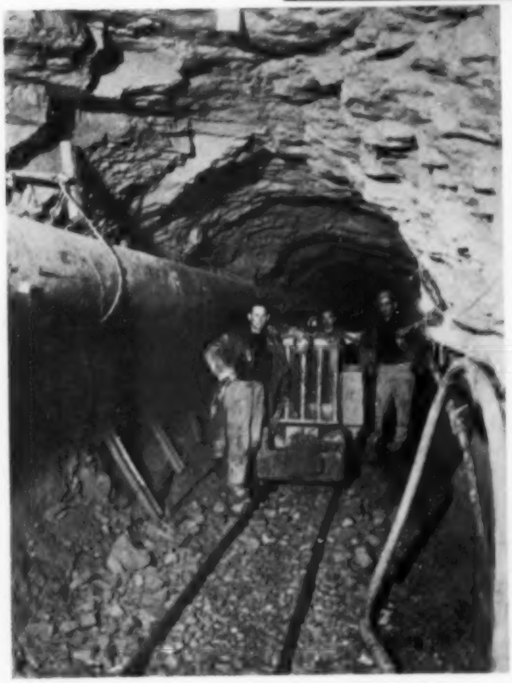
Slusher drifts are placed on 34-ft centers (three car lengths) to allow loading from several drawpoints at once.

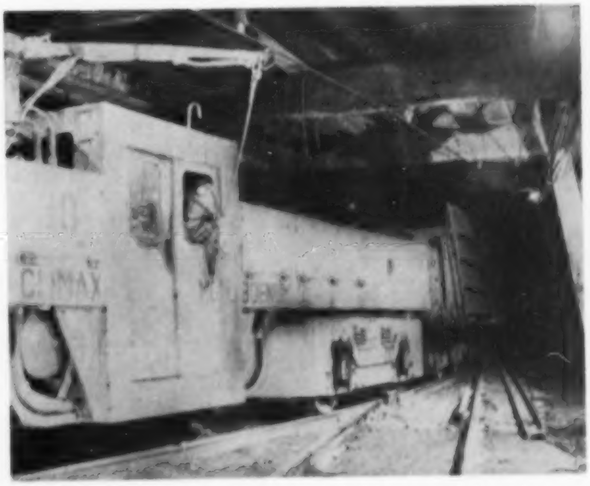
On new development, the grade is kept to 0.5 pct or less wherever possible. Although usually less than 0.4 pct in the loading drifts themselves, grade facilitates drainage in areas that accumulate water.

All trains are loaded downgrade, as it is extremely difficult to move a loaded train upgrade from a complete stop. The downgrade corresponds to the ventilating system, and the train is faced into the fresh air stream. This reduces the number of men exposed to dust created by loading. All drawpoints are equipped with small sprays.

Haulage Methods and Equipment: All level haulage at plant F is by rail using electric trolley locomotives. Although there are battery locomotives in the mine, they are generally restricted to use by development crews.

Rubber tire shuttle seen above and at right offers great mobility and operates in either direction. Time is saved in loading and discharging. Hauling demands greater tonnage and better breakage.





Convenience and flexibility are gained by the use of diesel locomotive shown at left while speed and larger output result from the system shown above.

Outside the mine in switching and dumping areas, in the portal and around the fringe drifts, 90-lb rail is used. In the loading drifts a 60-lb rail is used.

Motor generator (MG) sets are installed at eight places to provide dc power to the trolley system. On No. 1 level there is one set at the crusher and two at the portal outside the mine. Three are installed underground at strategic places. On No. 2 level there is one at the crusher outside the mine and one at a main loading drift on the footwall.

Four hundred and forty volts ac are delivered to the MG sets and 275 volts dc from the MG set to the trolley line. In theory, 250 v are available at almost any point on the trolley line, but in fact, the voltmeters on some of the locomotives show an available line voltage between 220 v and 250 v.

The State mining code prohibits dc voltages greater than 275 v underground. Direct current is considered safer because of a lesser tendency for spasmodic grasping of hot wires, and it has added advantages of flexibility in use and installation and in the locomotives themselves.

At present there are 11 Atlas 19-ton, 4-wheel locomotives and 7 General Electric 20-ton swivel-truck 8-wheel locomotives in use. The Atlas locomotives are used on the No. 2 level, each hauling 22 cars. On No. 1 level, the Atlas locomotives haul 20 cars and the G. E. locomotives 22 cars. The locomotives and the first four or five cars are equipped with air brakes, which may be operated independently or together. The locomotives also have mechanical brakes, and the G. E. locomotives have dynamic electric brakes.

Cars used at mining plant F are the Granby side-dumping type of two makes. The Lake Shore Mfg. Co. type is rated at 200 cu ft and the Card Car Co. type at 190 cu ft. Actual capacity, level with the ends, is 193.4 cu ft for the Lake Shore type and 181.4 cu ft for the Card type. Car dimensions are given in Table X.

The car factor (i.e., the tonnage actually carried in each car) for the first 11 months of 1955 was 9.08 tons on No. 2 level and 8.20 on No. 1 level.

On No. 2 level there is only one dump block, as there is only one crusher. On No. 1 level there are three dump blocks, two for regular grade and one for the low grade. All are on one track. For this reason provisions are made to move the dump blocks out of line of the dump wheels and pass cars, undumped, to whichever ore bin is desired.

Car cleaners are utilized. Essentially the car cleaner is a pneumatic ram with a toothed bar at the end, installed in line with the dump blocks. When the cars are in dumping position with the door open, the cleaner may be pushed into the car and along the car bottom, loosening any muck that sticks.

A cleanup crew is composed of several experienced leadmen to operate equipment and direct the work and to indoctrinate all new men coming to the mine. An Eimco E-40 mucking machine (electric trolley) is used in conjunction with shovels in drifts that have become fouled with spilled muck or other material.

Loading crews are responsible for cleaning up spills as they occur, so that most drifts can go for a considerable time before it is necessary for the cleanup crew to work in them.

Without cleanup, derails become common. Many trains can be tied up by one derailment, especially on the fringe drifts and in the adit.

Haulage Communication System: Dispatchers are stationed outside each portal and inside where the first branching of tracks within the mine takes place (No. 1 switch). The inside and outside dispatchers can communicate with each other and with the ore bins and crusher by telephone. The inside dispatcher is also connected to various points within the mine by telephone and to the rest of the plant by a Bell telephone.

In addition, all the haulage locomotives and many of the smaller locomotives used by nippers and cement crew are equipped with radio telephones operating through the trolley wire. Dispatchers on the No. 1 level are also so equipped, while only the inside dispatcher on the No. 2 level is hooked into the system. No. 1 and No. 2 levels are on separate frequencies so that there is no interference between the two.

In the loading drifts a system of buzzers or whistles is used by the brakeman or loaders to signal to the motorman. Throughout the mine, one signal means to stop, two to back up, and three to go ahead. If signals are given slowly the operation is to be done slowly.

Hauling and Loading Times and Distances: Hauling time is that interval necessary to go from No. 1 switch out of the mine, dump all cars, and return to No. 1 switch.

Loading time is the interval necessary to go from No. 1 switch around the fringe drifts into the loading drifts, load all cars, and return to No. 1 switch. In Table XI times are average for the first 14 days in December 1955.

Haulage Costs: Haulage costs per ton are summarized in Table XII.

Table XI. Hauling and Loading Times and Distances in Mining Plant F

Item	No. 1 Level	No. 2 Level
Haulage time	22 min	12 min
Loading time	50 min	24 min
Round trip time	72 min	36 min
Haulage distance	10,400 ft	9450 ft
Loading distance		
Longest	6,650 ft	
Shortest	1,750 ft	
Average normal	5,450 ft	2330 ft
Round trip distance		
Longest	17,500 ft	
Shortest	12,150 ft	
Average	15,850 ft	11,780 ft
Average speed		
Hauling	472.7 ft per min (5.4 mph)	787.5 ft per min (8.9 mph)
Loading	109 ft per min (1.2 mph)	97.1 ft per min (1.1 mph)
Total	220.1 ft per min (2.5 mph)	327.2 ft per min (3.7 mph)

Table XII. Haulage Costs Per Ton, Mining Plant F

Item	No. 1 Level	No. 2 Level
Payroll	0.104	0.061
Supplies	0.021	0.016
Power	0.006	0.003
Distribution	0.062	0.042
Direct	0.004	—
Total	0.197	0.112

Table X. Dimensions of Cars Used in Mining Plant F

Overall (center of coupling)	11 ft 3 in.	
Wheel base	4 ft 6 in.	
Track gage	36 in.	
Overall height unloaded	7 ft ⅛ in.	Card
	7 ft 1 in.	Lake Shore
Body length outside	9 ft 10 in.	Card
	9 ft 9½ in.	Lake Shore
Body width outside	6 ft 11⅝ in.	Card
	7 ft 4⅜ in.	Lake Shore

Mining Plant G

The three mines comprising mining plant G are primarily producers of zinc concentrates, mining sphalerite in a gangue of dolomite, which includes small amounts of chert.

The low grade orebodies require that mining be done on a large scale. In these mines jumbos break the ore, which is loaded by overcast loaders and conventional dipper-type shovels. Diesel trucks transport the ore from face to underground crusher. This report is concerned with the costs as applied to the haulage by truck and with the factors that have affected them.

Haulage Methods and Equipment: Two types of haulage units are used, a semi-trailer and the Koehring Dumptor. The Dumptor transported 87 pct of the tonnage hauled during the period covered by this summary.

The Koehring Dumptor carries an 8-ton load and is powered by a GMC 4-cylinder diesel engine. Driving tires are either 16x24 in. or 18x24 in. and steering tires 10x20 in. Braking is done by a hydraulic system. The unit dumps to the front, by gravity, and the loaded box rocks forward. Ejection of the load is swift and efficient and a minimum of time is spent at the grizzly. The Dumptor travels efficiently in either direction and requires little maneuvering at the loader. Maintenance of these units has been light and of a general nature.

The semi-trailer unit consists of a Dart tractor and a 10-ton trailer. The Dart is powered with a 4-cylinder Cummins diesel engine driving a single axle with dual wheels and mounted with air brakes. The gooseneck, two-wheel trailer, is a hydraulic rear dump, built without brakes or springs and riding on 12x24-in. tires. The tractor mounts 9x20-in. tires throughout. Maintenance of these vehicles has been of a routine nature.

Comparatively, the semi-trailer unit requires more maneuvering at the loader and at the grizzly and requires a longer dumping time unless provisions are made for stringing out the load. The trailer units are also used as a service vehicle to convey explosives and other supplies.

In general, it is apparent that washing, cleaning, and drying out the trucks (particularly the running gear) regularly and frequently prevents considerable costly repair work.

None of the trucks operate with scrubbers for the exhaust gases. It is believed that enough ventilation is available to keep the noxious gases below the critical concentration levels, and care is taken to keep the motors in the best operating condition.

For better evaluation of truck costs at individual mines, conditions of haulage and repair are listed.

Mine 1: The roadway in mine 1 is level except for a few short grades. It is constructed of broken rock with a top dressing of jig tailings consisting almost entirely of crushed dolomite. The water table is close to the floor of the mine and roads are wet but well drained. The surface of the roadway is hard and packed. It is maintained in good condition with a standard patrol grader and tailings added occasionally.

Average round trip distance for the current year is 6000 ft. Repair facilities are underground. Whenever possible, unit change-out is practiced, and the damaged section is sent to the surface shops for repair.

Mine 2: In road layout, construction, and maintenance mine 2 is essentially the same as mine 1. Average round trip distance is 3200 ft to one end of the mine and 5200 ft to the other end. A significant difference is that the repair shop is on the surface and is connected with the mine by an inclined adit. This permits driving a truck to the surface for repair and service in a dry, well lighted shop. The effects of this are readily apparent in the cost summary.

Mine 3: Mine 3 differs from mines 1 and 2 mainly in having considerably longer hauls and hauling more tonnage. Round trip distances to the shaft area from the three major orebodies are 4800, 5600, and 7000 ft. The majority of travel is in crosscuts on level, well made roads surface dressed with jig tailings. Road maintenance is by a patrol grader and must be done frequently and regularly. Repair facilities are underground, and unitized repairs are made whenever possible.

Cost Analysis: Following are explanatory notes related to the categories in the cost summary, Table XIII, p. 924.

Tons Hauled: This represents all loads hauled, development waste, tailings, and ore.

Repair Hours: As charged per vehicle.

Repair Labor Cost: As charged per vehicle.

Parts Cost: By inventory control.

Fuel-Oil-Lubrication: Fuel is charged direct per gallon, and oil and grease are converted to equivalent units to receive a basic charge.

Tire Cost: This figure is based on tires purchased and repairs from July 1954 to September 1955 and includes a 10 pct increase for handling, hoisting, etc. This represents a decrease of 1.4¢ over a comparable figure based on 1951-1952 experience. This is due primarily to the use of nylon tires, which resist casing breaks and permit more recaps. Also, improved road maintenance has lengthened tire life.

Operating Labor Cost: As charged per vehicle, regardless of type of load or service.

Mining Plant H

Mining plant H is in the process of changing some of its mainline haulage from mine cars and track to a belt-conveyor system. Because the conveyor system is not completely installed and fully in operation, any costs would be misleading. The following brief summary of haulage practices should be of value to mining men. Three systems of haulage are employed in the mine.

Mainline Belt Conveyor: Ore from continuous mining machines is conveyed with a system of belt conveyors to a mainline conveyor belt, which dumps into an ore bin of 2800 capacity. Ore is removed from this bin by a plow feeder and is transported by short conveyors directly to the hoisting shaft pocket.

Panel Belt and Track: Ore from continuous mining machines is conveyed with a system of conveyor belts to a 2500-ft panel belt, which dumps into mine cars that are hauled to the rotary dump and dumped into the ore hoisting pocket.

Conventional Loading and Track: Ore from Joy loaders is loaded into shuttle cars and dumped into mine cars by elevating conveyors.

Costs of the above systems are in the order listed, the belt conveyor being the cheapest.

Mining Plant I

Mining plant I is a medium-size zinc-lead mine having working conditions similar to those of plant A. However, mining and transporting systems are different in several respects.

Mining plant I produces 850 tpd, working two production shifts for five days a week. Of 70 men employed in the mine and mill, 45 work underground on two production shifts, and on mine development three shifts six days a week. Thus average ore output per manshift for all underground workers is 18.9 tons.

The zinc-lead ore at this mine is a replacement type occurring in siliceous dolomite limestone. The orebodies generally dip gently to the northeast.

The room-and-pillar method of mining is employed. Ore is extracted in large open stopes; no timbering for back support is necessary. Pillars are left for support where there is no ore or where the grade is too low for profitable mining. The backs are carefully scaled and examined daily for loose rock. Mechanical mining is done by a *Gismo*, a machine which drills, mucks, and transports ore in the stopes to the draw chute. The two Gismos used underground are diesel-engine-powered, self-loading transports, each supplemented with jumbos for drilling purposes.

Ore exploitation and development are from the main haulage adit that connects with an incline shaft, which extends to the 300 level at an inclination of 22° downward from the horizontal and to the 500 level at a steeper inclination. This shaft serves the 100, 200, 300, and 500 levels. The 100 level is exhausted; the 200 and 300 are ore producing levels at present; 500 is a development level.

Haulage Methods and Equipment: Trolley locomotives are used on the main haulage level, and both trolley and storage battery locomotives serve the other levels.

A single-drum, electric-driven hoist situated at the top of the incline shaft on the main haulage level is used to transport men, ore, and supplies to and from the different levels.

An Allis-Chalmers HD-5 diesel crawler tractor equipped with an exhaust gas conditioner is used to operate the trackless, self-loading transport and move the drill jumbo.

The crawler tractor is powered by General Motors 2-cylinder, 2-cycle, direct-injection diesel engine, with 4¼-in. bore and 5-in. stroke, developing 40.26 hp at drawbar and 50.25 hp at belt. Governed at full load the engine runs at 1800 rpm; at maximum torque it runs at 1000 rpm. Piston speed is 1500 rpm.

At rated engine revolutions per minute crawler tractor speeds are as follows: first, 1.46 mph; second, 2.44 mph; third, 3.30 mph; fourth, 3.96 mph; fifth, 5.47 mph; and reverse, 1.99 mph.

Use of these two machines has increased production per manshift and lowered the cost per ton of ore recovered materially. Formerly slusher hoists with scrapers were used to move the ore in the stopes to the draw chutes.

The exhaust gas scrubbers are mounted at the rear end of the crawler tractor and several feet back of the operator's seat. When filled the scrubber contains 20 gal of water. Approximately 15 gal are consumed during one working shift. At the beginning of the first shift 20 lb of sodium sulfite and 15 oz of hydroquinine are added, and 15 oz of hydroquinine and enough water to fill the tank are added at the beginning of the second and third shifts. At the beginning of the fourth shift the scrubber tank is thoroughly cleaned and both sodium sulfite and hydroquinine are added as previously stated.

The Gismo operator tests the atmosphere with a colorimetric carbon monoxide indicator and makes

Diesel self-loading transport loading ore from stope underground.

The 5-ton locomotive puts out 4400-lb drawbar pull and hauls nine Grandy car trains. Each car weighs 3¼ tons. Load weighs 5¼ tons.

a record in a book of the results of his daily tests. Whenever any carbon monoxide can be detected in the mine atmosphere, the Gismo operator has orders to shut the machine down until repairs and adjustments to the engine have been satisfactorily performed. The mine is ventilated by a large-capacity fan and auxiliary blower fans with tubing. The State mine inspector also makes periodic safety inspections and tests for carbon monoxide and oxides of nitrogen with suitable portable indicating devices.

Transportation or mining costs were not made available.

Mining Plant J

Haulage Methods and Costs: Mining plant J, one of the newer copper mines in the U. S., has utilized trackless haulage since it was started.

The underground haulage unit, equipped with a 275-hp diesel engine, transports approximately 15 tons of ore from the working area to the dumping point. Gross weight of the vehicle is 70,000 lb. The predicted haulage radius of the unit is approximately half a mile from the dumping point. Present costs on the units now operating are as follows:

The production labor for operation is 0.063¢ per ton. Material production cost is 0.013¢ per ton, or the aggregate production cost of haulage is 0.076¢ per ton. Maintenance labor on the ore haulage units is 0.035¢ per ton. Material cost for maintenance work is 0.055¢ per ton, which is an aggregate of 0.090¢ per ton of ore. A cost of 0.080¢ per ton for tires should be added to these figures. This makes an overall total of 24.6¢ per ton ore haulage.

Operating conditions under which the trucks are utilized are severe. Road conditions are poor and no means of improvement has been found at this time. It is believed that if adequate hauling roads could be sustained, a better figure could be obtained regarding maintenance and tire costs. Trucks operate in an 8-ft horizon. This does not allow any subgrade to be built into the road bed; therefore, undulations in the floor cannot be corrected satisfactorily without cost in excess of that required to operate the trucks under present conditions.

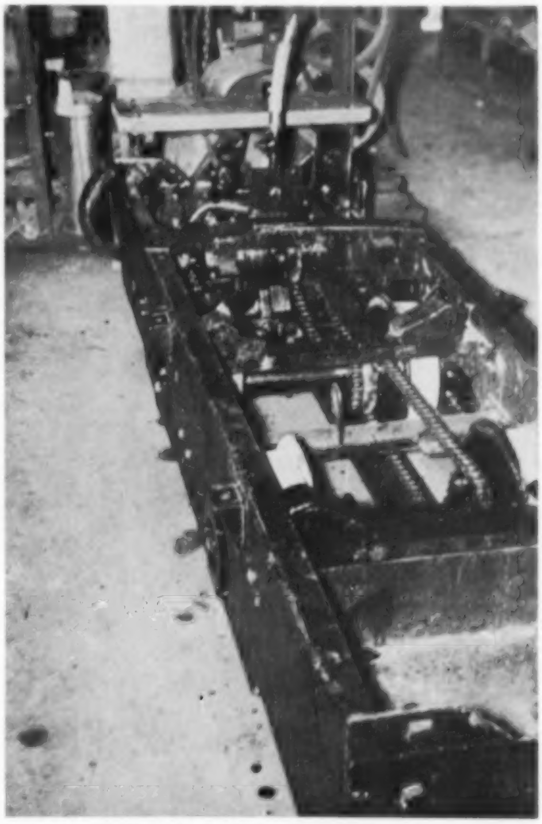
Mining Plant K

Mining plant K is an example of a mine utilizing compressed air trammers. It produces 200 tons of gold-silver ore a day by working two shifts on six days a week. The mill feed has a gold-silver ratio that ranges between 1:5 and 1:10 with 1:8 average. The mill is also operated on two shifts six days a week. A gold-silver concentrate is produced. The tailings from the flotation units can be treated by cyanidation to produce a mechanical mixture of gold and silver bullion. Of 67 men employed, 47 work underground. The average ore produced per manshift for all underground employes is 4.25 tons.

The current production of gold-silver ore is mined from a common vein system. The veins are in silicified andesite. The rock walls, high in feldspar content, slake quickly when exposed to air and moisture. Rapid kaolinization results in talcky, blocky, and heavy ground. Stress adjustments occurring after introduction of quartz-vein filling resulted in movement along vein walls, and in cross-faulting and brecciation of vein quartz; this resulted in physically weak ore and rock masses.

The mine is operated through an inclined three-compartment timbered shaft that dips 52½° between the shaft collar and a point 50 ft below the 600 level from where the dip increased to 65°

Original air-trammer as it appears today with slight modifications. Handles two 32-cu ft rocker dump cars easily.



A rebuilt Tramaire chassis ready to go back into service. Special features include lower motor to axle sprocket ratios for increased speed and range. Starting torque is seemingly not affected.

throughout its length. Mine levels are 125 ft apart vertically, except between the 700 and 800 levels, which are 150 ft apart. Each level has a timbered shaft station and a skip pocket of 100-ton capacity.

Shrinkage, cut-and-fill stopes, and square-set timbering filled with waste fill (where the vein is wide) are employed to recover the ore. In the shrinkage and square-set stopes, 1-in. diam slotted wedge-type steel rock bolts and 6x6-in. bearing plates ⅜ in. thick are used to pin the hanging wall where necessary.

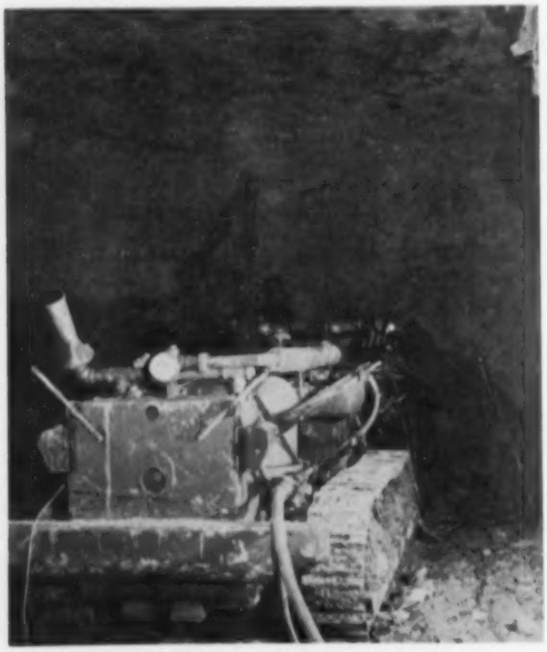
Recently shrinkage stopes and square-set timbering filled with waste have been discontinued and only cut-and-fill stopes and square sets with a prepared sandfill are now employed to recover the ore.

Haulage Methods, Equipment, and Cost: Formerly hand tramming was practiced on all operating levels of mining plant K. In 1947 an adjoining mine introduced a trammer operated by compressed air (Universal Tramaire) to replace hand tramming.

That mine subsequently discontinued development work, and mining plant K eventually rented the unit for trial purposes. Despite its crude appearance this little trammer did so well that all levels have been equipped gradually with air-powered machines. The little *hot rod* has been relegated to development levels, one after the other, and is still pounding away on a long development tram day in and day out.

A second unit (Tramaire) was purchased early in 1951 but was of the later design. This unit is powered exactly the same as the old prototype, i.e., a Gardner-Denver geared air motor having a nominal rating of 4 hp. The only significant difference was a 50-cu ft receiver instead of a 42-cu ft receiver.

A third unit, purchased in January 1952, was identical to the second unit (Tramaire) except that a 6-hp motor was specified. The increase in horsepower made so noticeable a difference in performance that the power plant in the second unit was converted to 6 hp by the simple expedient of changing cylinders and pistons.



Utex Jumbo with Ruth diesel exhaust gas conditioner.

A fourth unit was purchased in March 1954. This is an Eimco 401 air locomotive, which has a 58-cu ft receiver, a 7½-hp air motor, and two-speed transmission.

A fifth and most recent unit was placed in service on December 6. This is a Universal Tramaire, with a 36x84 receiver (50 cu ft) and a 10-hp G-D air motor. Although this unit has only been operating a short time, its performance is so dramatically improved that air trammers appear to be the efficient machine for this plant.

The experience with the various air trammers has not been exactly inexpensive, and a large number of revisions have been made. However, once the revisions have been made, performance and durability have been outstanding and it is believed that the added investment has been worthwhile.

All four Tramaires have interchangeable axle assemblies, and only one spare set of wheels, axles, and sprockets need be kept on hand.

The improved performance of the 10-hp model lies in both the speed (and load-pulling characteristics) and the noticeably reduced air consumption. Whereas the 6-hp model can handle only three cars, the 10-hp engine handles four with about 50 pct less charging. Also, the air motor will still handle the train when the receiver is nearly exhausted, whereas the smaller motors require substantially greater pressures at stalling speeds.

The approximate weight of the later model Tramaires is 2800 lb, while the Eimco 401 is shipped at 3260 lb. Mine management found it expedient to build a box between the frame members at the front of the Tramaires where 250 lb of ballast in the form of 1½-in. grinding balls can be carried to aid in keeping the forward drivers on the rails so the net effect is a locomotive of about 3100 lb.

Mine cars have been standardized on a Coeur d'Alene hardware rocker dump car of nominal 32-cu ft capacity. This car is shipped at a weight of 1600 lb. The average car factor, using that type of car, is 1.44 tons, which produces a gross car weight of 4500 lb. Two 32-cu ft cars are hauled by the 4-hp unit, three by the 6-hp units, and four with the 10-hp unit. Actually the new motor would handle a longer train comfortably, but tail room on the stations for longer trains is lacking. With fewer curves, and a lighter grade (now 0.75 pct), the motors would handle a much greater load on less air.

Table XIV. Mining Plant L Costs for First Half of 1955

Supervision	$2,236.49	
Underground labor*	40,702.33	
Surface labor**	301.27	
Repair labor†	7,596.78	
Miscellaneous	395.99	
Total direct labor	$51,232.86	
Timber and lagging	$2,132.61	
Mine tools	57.41	
Pipe fittings	43.52	
Other supplies‡	5,748.24	
Total direct supplies	$7,981.78	
Electric power	$1,267.94	
Garage charges	35.75	
Social Security taxes	1,892.12	
Total misc. direct	$3,195.81	
Total direct costs	$62,410.45	= $0.201 per ton of ore trammed

* Includes loaders, motormen, timber repairmen, and labor for concreting.

** Includes track repair and snow removal on section from adit portal.

† Includes mechanical and electrical labor for car and locomotive repair.

‡ Includes rails, mechanical and electrical supplies for cars and motors, and pre-mix concrete.

It is difficult to express the distance traveled in terms of an average. However, the longest distance now is 1300 ft, and most of the production is from stopes 1000 to 1300 ft from the pockets, currently.

The speed of these motors, at full throttle, is 4 to 5 mph. However, charging time will cut that speed in half.

Air consumption varies drastically with the various units because the loading is not the same. However, it is noted that the 6-hp units will require charging on the station, plus two intermediate rechargings, to reach the maximum distance with only three cars.

The tonnage handled varies greatly from level to level and from day to day. As much as 100 tons per shift (one man working alone) has been trammed from a distance of 800 ft. As yet, there has been no opportunity to keep the newest motor busy for a full shift, and its daily capacity cannot be known.

Maintenance costs through the rebuilding stage have been high. However, since all the new components have been installed, there has been virtually no maintenance. Chain is the greatest single item of repair, and this has become insignificant in the last year or so. Each unit uses approximately 13 ft of chain (RC-80) at a cost of $2.50 per ft. Barring accidents, chains now last for more than a year and haul 15,000 to 20,000 tons each.

The air-powered trammers, with the exception of the first, have all cost about $2,000 delivered, plus the cost of replacing the running gear assemblies.

Mining Plant L

Mining plant L is a medium-size metal mine producing lead and zinc ore containing variable amounts of subordinate minerals, which include silver, gold, cadmium, cobalt, and bismuth. Rail haulage has been practiced by utilizing trolley and storage battery locomotives at this mine. A diesel locomotive is used at another mine under development and operated by the same company.

Mining plant L has been in continuous operation for 71 years and the aggregate length of the mine workings is more than 78 miles.

The mine is opened by a main haulage adit 10,000 ft long, and a main underground three-compartment shaft inclined at about 50° and connecting with the lower working levels.

About 1200 tpd are produced with an underground labor force of 570 men.

Haulage Methods, Equipment, and Costs: At mining plant K, the mine tram (adit) is 10,000 ft long on a 0.38 pct grade in favor of the loads. Eight-ton trolley locomotives are used on 18-car trains. Each car has a capacity of 4.3 tons or 77.4 tons of ore per train. The empty cars weigh 2 tons each. Therefore, the locomotives handle more than 100 tons when the trains are loaded. The track is 24-in. and is 90-lb relay rail. Two 18-car trains operating two shifts a day do the tramming.

A list of the costs for the first six months of 1955 are given in Table XIV. They cover 310,552 dry tons of ore trammed and include the timber repair costs for the 10,000-ft adit. For the past two years, sections of the adit have been concreted. The following costs also include the cost of some of this work.

The 5-ton diesel locomotive now operating in another mine of the same company is powered by a 40-hp 4-cycle Buda engine. It handles eight cars of 4.3-ton capacity on a 4000-ft tram. The grade is 0.2 pct in favor of the loads. The locomotive is not working at its capacity and definite cost for tramming cannot be given. At present, the locomotive is working less than 30 hr a week. One hour every other week is spent on routine servicing.

After 15 months, or 2000 hr of operation, the locomotive was overhauled. It was necessary to put on new drive sprockets and chains. New valves, piston rings, and cylinder head were put in the engine.

Mining Plant M

Mining plant M is a medium-size metal mine producing zinc, lead, and silver ore in which rail haulage has been practiced by utilizing trolley, storage battery, compressed-air, and diesel locomotives.

Mining is accomplished by the horizontal slice, timbered, cut-and-fill method.

The 2000-level adit and mine are ventilated by a main Axivane fan of 4-ft diam mounted on the surface and operated blowing. The fan delivers 57,000 cfm.

A total of 350 men are employed daily on three shifts of which 200 work on the day shift. Approximately 900 tpd are produced.

Haulage Practices, Equipment, and Costs: The ever-rising cost of labor and supplies has made more urgent the need for reducing mining costs. One of the high-cost phases of a mining operation is materials handling, especially so at this mine where several transfers are made before the material reaches the working place.

The rail in this mine is 30-lb on 24-in. gage laid on 0.4 pct grade on the levels. Maximum haulage distance is about 1800 ft. Storage battery locomotives of 3, 4½, and 6 tons are used on the levels, of which 19 are in service. In addition, there are three 1½-ton trammers and two compressed air locomotives that are used for short hauls on new levels.

Until recently all haulage from the mine to the main shaft was accomplished with two 8-ton 75-hp 275-v trolley locomotives. Two 4-ton 275-v locomotives were used for other service.

The new 2000-level main haulage adit was driven at 0.5 pct grade on 24-in. gage with 70-lb rails. Two Plymouth Model DDT 10-ton, 100-hp four-wheel diesel locomotives are used for haulage. They are equipped with Allison 400 series hydraulic torque converters. They are powered by G.M. Model 3-71-70, 2-cycle, direct-injection diesel engines, which develop 100 hp at 2000 rpm. Recently, one of them was clocked at full speed on the downgrade at 24.3 mph with no load. Haulage distance is about 8500 ft.

Also in service on the new haulage level is a Plymouth 5-ton diesel locomotive powered by a Buda Model 4 BD-182, 4-cylinder, 4-cycle diesel engine of 3¾-in. bore and 4⅛-in. stroke through a Fuller Model 12-S hydraulic torque converter. The engine develops 40 hp at 2400 rpm. Locomotive speed is 2, 3, 6, and 9 mph at 1000 rpm; 2.8, 4.2, 8.4, and 12.6 mph at 1400 rpm; 4.2, 7.1, 14.2, and 21.4 mph at 2400 rpm. Eight hundred to 900 tpd are being hauled in special Neymatic 8-ton cars. The cars are loaded automatically with a weigh-loader at the shaft and are dumped at the discharge point by means of two rollers, which travel in an arc and engage with *dumping irons* at each end of the car. The body is hinged at the side of the car so that the truck remains on the track while the body is turned over. Primary crushing is done underground.

Ore and waste is hauled on the levels with Rocker dump cars holding 50 cu ft when level full, or a

Five-ton locomotive being powered by a 40-hp 4-cycle Buda engine with scrubber unit mounted on side.

load of about 3.4 tons. The car is made locally and weighs 2285 lb.

Haulage cost for the first ten months of 1955 is $0.42 for main haulage, $0.70 for haulage above the 4000 level, and $0.23 a ton for haulage below the 4000 level.

Mining Plant N

Mining plant N is a new metal mine and still in the development stage. The main minerals in the orebodies consist of pyrite, pyrrhotite, chalcopyrite, and cobaltite.

Rail-haulage is practiced by using principally diesel and storage battery locomotives.

The altitude of the mine workings ranges from 6852 ft to more than 7400 ft. The main 6850 level is the main haulage adit which was driven about 6400 ft into the northerly side of a canyon. Levels have been established at 100-ft vertical intervals from 7100 to 7400 ft above sea level.

Ore occurs in irregularly shaped pods that cut across the bedding and schistosity of the schists, quartzites, and argillites, which comprise the country rock. Stoping is accomplished by cut-and-fill, square-set and fill, or sometimes rock bolt and fill, according to local conditions. Classified mill tails are used for fill, and the fill is poured to within working distance of the back as soon as possible after the horizontal slice has been stoped.

Approximately 750 tpd are mined by 150 underground employes.

The mine is ventilated by an underground reversible-type main fan operated exhausting, located in a run-around drift near the portal of the 6850 level. The fan circulates 30,000 cfm of air through the mine.

Haulage, Methods, and Costs: One-ton Mancha storage battery locomotives have been used principally for nipping and by drift crews on the upper levels where the tramming distance is not great. In drifting, about 2000 ft is the maximum tramming distance in which 1-ton locomotives pull five 1700-lb cars, each carrying about 1½ tons of muck. Occasionally, they are used for tramming ore from stopes. On the 7300 level, a Mancha locomotive is used to pull two 4000-lb cars, with 2.6 tons capacity each, for a round-trip distance of about 500 ft. On a full-shift basis a crew could average 50 round trips.

On the upper levels two Plymouth 5-ton diesel locomotives, with 60-hp Buda 4-cycle diesel engines, are employed. The first was placed in service on Oct. 1, 1951, and the second on Dec. 20, 1952. Only one is used on the main ore haul, pulling an average of eight 4000-lb cars, with 2.6 tons capacity each, for an average round trip distance of 1600 ft on ten round trips per shift Average train speed is about 4 mph, and fuel costs 15.1¢ per gal at the mine; daily fuel consumption is about 16.7 gal for the two locomotives. One engine has been replaced and that replacement was due to an accident. The new engine cost $522.00. Engine operation before overhaul is about 5000 hr, and daily repair and maintenance costs for each locomotive average $12.88.

Two 8-ton Plymouth locomotives, each driven by a Hercules Model DRXC diesel, 4-cycle indirect-injection engine with a rating of 150 hp at 2200 rpm, are used on the 6850 main haulage level. The first was placed in service on Dec. 12, 1949, and the second on June 1, 1954. One of these locomotives is used continuously on the ore haul three shifts per day; however, the locomotives are interchanged to suit the situation. The second locomotive is considered a spare and is used one or two shifts per day on other work. On the ore haul, the locomotive pulls 6 cars, each weighing 6300 lb and carrying 8.3 tons. The average round trip distance is 9000 ft

Table XIII. Truck Haulage Costs from Oct. 1, 1954, to Sept. 30, 1955, Mining Plant G

Unit Used	Tons Hauled	Repair, Hours Per Ton, $	Repair Labor, Cost Per Ton, $	Repair Parts, Cost Per Ton, $	Fuel-Oil-Grease, Cost Per Ton, $	Tires, Cost Per Ton, $	Total Maintenance, Cost Per Ton, $	Operating Labor, Cost Per Ton, $	Total, Cost Per Ton, $
Mine 1									
Trailer	65,784*	0.018	0.049	0.036	0.012	0.020	0.118	0.080	0.198
Koehring	148,231*	0.016	0.047	0.028	0.009	0.020	0.105	0.087	0.191
Average cost		0.017	0.048	0.031	0.010	0.020	0.109	0.085	0.194
Mine 2									
Koehring	136,959	0.005	0.009	0.009	0.007	0.020	0.045	0.066	0.111
Mine 3									
Koehring	223,317	0.021	0.054	0.041	0.10	0.020	0.124	0.108	0.232
All Mines									
	574,291	0.015	0.041	0.030	0.009	0.020	0.099	0.089	0.188

* Total tons hauled 214,015.

with six trips per shift. Average train speed is 7 mph, and daily fuel consumption is 24.9 gal for the two locomotives. Neither locomotive has had its engine replaced; new rings are installed at 4000-hr intervals and a complete overhaul is performed after 6500 hr of operation. Repair and maintenance costs averaged $12.41 a day for each locomotive.

All diesel locomotives are equipped with exhaust gas scrubbers.

Conclusions

Diesel motors are far superior to gasoline motors in haulage operation of all types underground in all respects as to safety, efficiency, and costs.

Tire costs are excessive on large trackless haulage units and they are a critical item on all units; the field is wide open for developing better tires. The hydraulic tire is reported to be a hope.

Unless a good roadway can be maintained, trackless haulage is excessively costly.

Diesel locomotives, trucks, bulldozers, and other diesel-powered equipment are fast proving their superiority for mine transportation purposes.

There are a few instances where a direct comparison can be made between battery-powered, trolley-electric-powered shuttle cars, cable-reel cars, or locomotives in the same mine.

Where physical conditions, life of the mine, production, steady working time, and undoubtedly other factors are available, belt conveyor systems provide the lowest transportation costs. Trolley haulage is on its way out in metal mines.

Transportation costs range from 10¢ to 42¢ per ton. Twenty-five cents a ton appears to be an average cost at this time.

Acknowledgment

Acknowledgment of indebtedness for aid in collecting data for this report is made to officials of metal mining companies throughout the metal mining areas of the U. S. Because this report covers haulage cost data furnished by individual companies, it is not possible to set forth the names of officials or the companies they represent. However, the author wishes to express his sincere appreciation of the excellent response from everyone concerned in compiling pertinent information as a contribution to the advancement of haulage practices within the metal mining industry.

Discussion of this paper sent (2 copies) to AIME before Nov. 30, 1956 will appear in MINING ENGINEERING and in AIME *Transactions*, Vol. 205, 1956.

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Abstracts

Debismuthizing of Lead

by T. R. A. Davey

(Journal of Metals, page 341, March 1956; AIME Trans., vol. 206)

The fundamental principles by which bismuth may be removed from lead by pyrometallurgical processes are enumerated. Qualitative discussion of the phase diagrams concerned is followed by presentation of quantitative diagrams. Brief mention is made of the practical aspects. Data presented show how chemical lead (>0.005 pct Bi) may be produced by the Jollivet, Dittmer, and Kroll-Betterton processes.

Separation of Germanium and Cadmium from Zinc Concentrates by Fuming

by H. Kenworthy, A. G. Starliper, and A. Ollar

(Journal of Metals, page 682, May 1956; AIME Trans., vol. 206)

Vapor pressure determinations were made on synthesized germanium sulfides. Germanium and cadmium were removed from sphalerite concentrates by fuming. The fume was retreated to separate some of the cadmium from the germanium and, at the same time, upgrade the germanium to more than 5 pct.

Reaction Zones in the Iron Ore Sintering Process

by R. D. Burlingame, Gust Bitsianes, and T. L. Joseph

(Journal of Metals, page 853, July 1956; AIME Trans., vol. 206)

Despite almost fifty years of commercial practice, the sintering of iron ore has received little fundamental study. One method of attack is to arrest the sintering zone after it has progressed part way through the bed. The same general method was developed independently in the present investigation to study partially sintered beds typical of American practice. Dissection procedures were developed for immediate and accurate sampling of all the zones in partially sintered beds. The chemical composition changed gradually across the various zones. Methods were developed for impregnating and sectioning partially sintered beds of iron ore. This permitted a study of the very narrow sintering zone, which advances as portions of the charge soften, fuse, and merge into the cake of sinter.

Discussion

Anionic Flotation of Quartz

by C. C. DeWitt

(Mining Engineering, page 66, January 1955; AIME Trans., Vol. 202)

The negative charges on diaphragms of quartz, tungstic oxides, stannic acid, acid dyestuffs, soaps, and glass have for a number of years been explained on the basis of chemical equilibria—a hydrogen ion or light metal ion passes into solution leaving the solid complex ion negatively charged.

While there are a number of observations which indicate a proportionality between the ζ potential and the streaming potential it should be recognized that all the experimental evidence thus far presented shows that if hydrogen ion concentration is kept at a constant value, electrokinetic phenomena are influenced by salts. The multivalent ions exert the greatest effect on the reduction of osmotic flow. In the interpretation of all electrokinetic data the assumption is made that the potential of the solid remains constant. That this is not true is evidenced by the values of ζ potential for quartz in contact with conductivity water as reported by the several investigators and by the authors of this paper. It is apparent that the nonreproducibility of surfaces will always prevent the obtaining of exactly comparable data. At best the experimental technique described depends on a theory which is capable only of showing a trend—another quartz surface should exhibit similar but not identical potential curves.

It seems entirely reasonable to assume that the negatively charged laurate ions should have little or no attraction for a negatively charged quartz surface. The weight of previous experience in selection of flotation activators points unerringly to the usefulness of the multivalent metallic ions.

The primary reason why the divalent barium ion is not available to two negative charges on the quartz surface might easily be that of distance between such adjacent negative charges. Otherwise activation could not occur, and the quartz could not assume the remaining unit positive charge of the barium ion. For this case no electrical double layer theory seems necessary. Clearly this is, at the negatively charged quartz surface, a case of partial chemisorption of the cationically divalent barium ion followed by the anionic neutralization of the remaining cationic charge by the freely moving laurate ion.

It is hoped that the authors will continue with this interesting technique and that their results will continue to indicate trendwise what is known about the

theory of chemisorption. Theirs is an excellent approach to an answer for the question: How shall one obtain a true, a usable measure of differential electron-sharing possibilities of a given polar group for a particular group of minerals or for two different numerals.

A. M. Gaudin and **D. W. Fuerstenau** *(authors' reply)*—The authors are pleased that their work has interested Dr. DeWitt enough to encourage him to take the trouble to send a written discussion. They are especially pleased that Dr. DeWitt shares with them the feeling that streaming potential studies constitute an approach which can greatly help understanding the flotation process.

Quite possibly the authors have failed to stress the reproducibility of their data. The experimental measurements recorded in the charts were sometimes obtained on different quartz plugs and sometimes several months apart, yet the points representing the measurements fall on the same curves. This is an instance of extraordinarily good reproducibility. Accordingly, we interpret Dr. DeWitt's comment on nonreproducibility of surfaces to refer to the difficulties in interpretation of streaming potentials in terms of calculated ζ potentials. As we have indicated in our own paper and as is further discussed in detail in the thesis by D. W. Fuerstenau, such phenomena as surface conductance play a major part in the calculation, and to date a perfect assessment of these various factors is not available.

We hope Professor DeWitt will find it possible to devote some of his research effort to the further study of streaming potentials.

Discussion

Particle Size and Flotation Rate of Quartz

by W. E. Horst, T. M. Morris

(MINING ENGINEERING, page 415, April 1956; AIME Trans., Vol. 205)

W. E. Horst—In regard to the flotation rate being described as "first order" for flotation of quartz particles below 65 μ in size (or any size studied in this work) in this paper, it appears that the authors' conception of rate equations is not in agreement with cited references.

A first order rate equation has as one of its forms the following:

$$\ln \frac{a}{a-x} = kt$$

where a = initial concentration, $a-x$ = concentration at time t, t = time, and k = constant. The constant, k, has the dimension of reciprocal time which is similar to the specific flotation rate, Q, described by Eq. 2 in the authors' article, as has been previously discussed by Schumann (Ref. 1 of original article).

The plotted data presented in Fig. 4 of the article utilizes the specific flotation rate, Q (min.$^{-1}$); however, there is not adequate data given to indicate the order of the rate equation which describes the flotation behavior of the quartz system studied.

Results from the experimental work indicate that the relationship between rate of flotation (grams per minute) and cell concentration (provided the percent solids in the flotation cell is less than 5.2 pct and the particle size is less than 65 μ) is described by an equation of the first order ($R_s = k\,c_s^n$, n being equal to 1 in this size range) and the use of the first order rate equation does not apply. Similarly the relationship for other particle size ranges studied is expressed by equations of the second or third order depending on the magnitude of n.

T. M. Morris—The authors are to be commended for the experiments which they performed. As they state in their discussion the concentration of collector ion in solution did change with change in concentration of solids in the flotation cell. Since for a given size of particle, flotation rate increases with concentration of collector until a maximum is reached, the effect of concentration of particles in their experiments was to vary the concentration of collector ions.

A collector concentration which insures maximum supporting angle for all particles eliminates the unequal effect of collector concentration on various sized particles and the effect of size of particles and concentration of particles upon flotation rate could be more clearly assessed.

I believe that if the authors had increased the concentration of collector to an amount sufficient to attain a maximum supporting angle for all particles they would find that the specific flotation rate of particles coarser than 65 μ would be constant with change in the concentration of solids in the flotation cell, and that a first order rate would apply to the + 65 as well as to the −65 μ sizes. It might also be discovered when this change in collector concentration was made that the maximum specific rate constant would be shifted toward a coarser fraction than when starvation quantities of collector are used since this practice favors the fine particles and penalizes the coarse particles.

P. L. de Bruyn and H. J. Modi *(authors' reply)*—The authors wish to thank Professor Morris for his kind remarks and for mentioning the influence of equilibrium collector concentration on flotation rate. With a collector concentration sufficient to insure maximum supporting angle for all particles, a first order rate equation may indeed be found to be generally applicable irrespective of size. Such a concentration would, however, lead to 100 pct recovery of the fine particles and consequently defeat the essential objective of the investigation to derive the maximum information on flotation kinetics.

To establish absolutely the validity of any single rate equation for a given size range, the ideal method would be to work with a feed consisting solely of particles of that size range. Use of such a closely sized feed would also eliminate the possibility of the interfering effect of different sizes upon one another.

The authors do not believe that increasing the collector concentration would shift the maximum specific flotation rate (Q) towards a coarser fraction. Experimentation showed Q to be independent of solids concentration for all particles up to 65 μ in size, whereas the maximum value of Q was obtained in the range 37 to 10 μ. Professor Morris contends that the addition of starvation quantities of collector favors fine particles at the expense of coarse particles, but the reason for this is not entirely clear to the authors.

The comments by Mr. W. E. Horst are concerned only with the concept of the term "first order rate equation." According to the usage of this term in chemical kinetics, *time* is an important variable, as is shown in the equation quoted by Mr. Horst. All the experimental results reported by the authors were obtained under steady state continuous operations when the rate of flotation is independent of time. To be consistent with the common usage of the "first order rate equation," it would be more satisfactory to state that under certain conditions the experimental results show that the relation between flotation rate and pulp density is an equation of the first order.

Discussion

Acid Coal Mine Drainage. Truth and Fallacy About a Serious Problem

by Douglas Ashmead

(Mining Engineering, page 314, March 1956; AIME Trans., Vol. 205)

In his paper Mr. Braley makes no mention of the bacteriological aspects of the problem. It is now quite well established that certain bacteria play a major role in formation of acid mine waters, and it is a simple matter in the laboratory to show that under sterile conditions the rate of acid production from a pyrites suspension is only about one quarter of that obtained from a similar suspension inoculated with drainage from a mine producing an acidic pit water. Under sterile conditions the oxidation is due to direct chemical action and, from the evidence just given and from much other evidence, this increase under nonsterile conditions is due to certain bacteria.

Experiments recently completed, and shortly to be published, have shown that this bacteriological oxidation can be prevented by the maintenance of pH conditions above 4. It was found that to raise this pH above 4 at the beginning of the experiments was not sufficient but that, due to the continuing chemical oxidation, alkali had to be added daily to maintain the pH conditions above 4. The amount of alkali added, however, over a fixed period, was only about one quarter of the alkaline equivalent of the acid produced when pH conditions were not controlled over an equal period. The opinion expressed by Mr. Braley that sodium hydroxide has little or no effect on the rate of oxidation of pyrites is not substantiated by the above experiments.

The writer does not claim that these results show a practical solution to the problems, especially in abandoned workings, but feels that the application of an alkaline coating, such as lime wash, to exposed accessible workings might be well worth trying.

S. A. Braley *(author's reply)*—In 1919 Powell and Parr[1] suggested that bacteria, or some catalytic agent, hastened the oxidation of pyritic or marcastic sulfur in coal. Carpenter and Herndon (1933)[2] attributed the action of Thiobacillus thiooxidans. Colmer and Hinkle (1947)[3] observed an organism similar to T. thiooxidans and another organism that oxidized iron. Leathen and Braley[4] first discovered this organism in 1947 in a sample of water from the overflow of the Bradenville mine (Westmoreland County, Pennsylvania). They characterized the organism in 1954[5] and gave it the name Ferrobacillus ferrooxidans. Although Temple and Colmer (1951)[6] had suggested the name Thiobacillus ferrooxidans, since they claimed it oxidized both ferrous iron and thiosulfate, we have found that pure cultures of the organism do not oxidize thiosulfate, hence the name F. ferrooxidans. In 1955 Ashmead[7] isolated an organism, similar to the one called Thiobacillus ferrooxidans by Temple and Hinkle, from acid mine water in Scotland. It is probable that this organism was F. ferrooxidans. In 1954 Bryner, Beck, Davis, and Wilson[8] reported microorganisms in effluents from copper mine refuse. These organisms appeared to be similar but were not in pure culture.

In view of this history of bacterial investigation of acid mine water and our own ten years of experience, we do not agree with Mr. Ashmead that bacteria play a major role in acid formation. We do not find that any of these bacteria will directly oxidize pyritic material. They do, however, augment the chemical formation of sulfuric acid by atmospheric oxidation. In two papers in 1953[9] Leathen, Braley, and McIntyre discuss the role of bacteria in acid formation and postulate the mechanism through which they operate.

Mr. Ashmead in his discussion of my paper has assumed that this work was carried on in the presence of acid mine water in which bacteria would be present. This was not the case. Strictly sterile conditions were not maintained, but the organisms present in mine drainages were definitely absent in these experiments. We believe that we have demonstrated that alkalis do not inhibit the chemical oxidation of pyritic material. This is also indicated by Mr. Ashmead's discussion in which he says that alkali must be added daily due to the continuing chemical oxidation.

It is interesting to note that Mr. Ashmead finds that maintenance of pH above 4.00 decreases the activity of the bacteria. We have found also that a decrease in pH below 2.8 also inhibits its activity. Table XIII of published data[10] illustrates the decrease in activity with increased acidity, although pH values are not given.

Table XIII. Increase in Acidity Attributed to Iron-oxidizing Bacteria

Culture	Acidity Increase for Periods, Pct		
	10 Weeks	22 Weeks	29 Weeks
III	161	356	84
IV	120	232	47
V	144	338	98

These values are in comparison with uninoculated controls and show the marked increase in acidity up to 22 weeks but a decline at 29 weeks, at which time the experiment was terminated. It is probable that after a longer period only chemical oxidation would have continued.

From our studies[9] we have postulated that the iron oxidizing bacterium (Ferrobacillus ferrooxidans) oxidizes the ferrous iron, resulting from chemical oxidation, to ferric iron. The ferric iron then aids the atmospheric oxidation of the sulfuritic material and is itself reduced to ferrous iron, which in turn acts as food for the autotrophic bacteria.

Study of the physiologic properties of F. ferrooxidans shows that its preferred pH is about 3.00 and its activity decreases with variation in either direction. It is extremely inactive above pH 4.00 and below 2.5. This inactivity above 4.00 is indicated by Mr. Ashmead's observations.

These properties of F. ferrooxidans then correlate perfectly with our hypothesis. Ferrous iron is oxidized very slowly by atmospheric oxygen in highly acid solution and since the bacteria become inactive, acid is formed only by atmospheric oxidation. At a pH of 4.00 or above iron is more readily oxidized by atmospheric oxygen, but the bacterial activity is decreased. However, with a pH above 4.00 the ferric iron is removed from the field of activity since its soluble sulfate hydrolyzes and precipitates the iron as ferric hydroxide or a basic sulfate. As we have shown in the paper under discussion, the alkali does not inhibit the chemical oxidation, and thus the acid formation continues. This

continuation would eventually reduce the pH to the active range of the bacteria, and they would augment the chemical oxidation until the pH became so low that they would become inactive and again only the chemical oxidation would prevail.

We are indeed appreciative of Mr. Ashmead's discussion calling to our attention a point which we did not mention in the paper. We believe that these facts substantiate our hypothesis of the role of bacteria in formation of coal mine acid.

As Mr. Ashmead states, regardless of the fact that alkali retards the activity of bacteria it does not indicate a solution to the problem, because of the inaccessibility of area of abandoned workings and the necessity for renewal of the alkali at intervals. Rock dusting constitutes such a procedure. Due to rapid removal of water from haulageways very little acid develops in these dry areas. Fresh working faces which are also rock dusted do not produce acid water. Evidence of the continuing acid formation in rock dusted areas is shown by the brown streaks of precipiated iron showing through the coat of rock dust. Such areas, once abandoned, loose the rock dust coat by neutralization and spalling, and its effect is soon lost.

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Discussion

Low-Temperature Carbonization of Lignite and Noncoking Coals in the Entrained State

by R. G. Minet
N. E. Sylvander
G. A. Vissac

(MINING ENGINEERING, page 54, January 1956; AIME Trans., Vol. 202)

R. G. Minet—The authors' description of the remarkable progress made in the last few years in applying the fluidized solids technique to the problem of lignite drying and carbonization clearly demonstrates that engineering techniques available today may make many processes practical and profitable which a few years ago were considered otherwise. As pointed out in the article, the future of the carbonization step hinges on the value and utilization of low temperature tar. On paper, at any rate, this tar looks like a valuable raw material for the chemical industry to use. Some 50 to 60 pct may be converted to pitch for electrodes, roofing, road tars, and other valuable products; the 25 to 30 pct tar acids could conceivably form a basis for a new low cost resin or plastic of the phenolformaldehyde type. Yet these materials are so new and dissimilar from available sources that much work must be undertaken by the chemical industry before they will be accepted. Now that the work of Dr. Perry and his colleagues has made a large supply of low temperature tar a real possibility, I would expect the chemical industry to accelerate its work in this field.

On the basis of certain data available in the literature it appears possible to produce a more aromatic tar, although in smaller yield, by operating at temperatures in the range of 1300° to 1500°F. Operating a fluidized bed process for lignite at these conditions should be technically possible, at least, and could produce a tar having more familiar characteristics. I wonder if Dr. Parry would care to comment on such a possibility.

Incidentally, in our own work on carbonizing coking coals in fluidized beds, using Ohio, Pennsylvania, and West Virginia high volatile bituminous coals, we have obtained yields which agree with the correlation given for tar yields vs moisture and ash-free volatile Btu. Our data are slightly under the line, but certainly in the range of the correlation. We have also obtained evidence in support of the authors' statement as to the effect of air on the process. In our pilot plant all the heat required for carbonizing is released by internal combustion of char in the fluidized bed in normal operation. We are also equipped to obtain all carbonization heat by external electric heaters on the shell of the carbonizer while introducing only an inert gas to the process. We note no difference in tar yield or characteristics between the two operations. In the case of the gas, however, it appears that some hydrogen is consumed by the air combustion.

We would be interested in hearing in a little more detail about the hot dust and char handling problems at Sandow. Have the authors found char subject to spontaneous combustion? Have they ever tried a coking coal in their pilot plant?

V. F. Parry *(author's reply)*—Production of a more aromatic tar by operation of the carbonizer at 1300° to 1500°F does not appear to be economical. 1) The capacity of a reactor operating at 1500°F would be 30 to 50 pct less than the capacity at 932°F and the cost of processing would increase materially. 2) The cracking of tar vapors in a reactor requires appreciable time to complete the reactions and it is doubtful that considering the very short time of residence of tar vapors within the reactor (4 to 10 sec after evolution) the basic character of the tar would be changed significantly. This is indicated from the data reported in Table XIV. 3) General studies have shown that it is advisable to operate at the minimum temperature to produce the maximum tar and minimum gas. 4) Operating problems and the maintenance of vessels and reactors, and the hazards of handling hot char, increase with the temperature of carbonization. It is technically possible to operate at temperatures as high as 1500°F, but in my opinion it is not economical or desirable. We believe that the primary tar must be won in the simplest way and then processed alone to change its character for production of desired products.

It is interesting to have confirmation of our observations on the reaction of air with the products of carbonization. The major reaction is with the char, fol-

lowed by hydrogen and then the tar vapors. We have observed that as the air/coal ratio is increased, the reaction with hydrogen increases, and with the ratio of 6 cu ft of air per lb of dry coal, some tar is consumed.

The hot dust and char must be handled extremely carefully without contact with air. It is explosively reactive if dispersed in air and it must be handled in a blanket of inert gas. After the char is cooled, it is subject to rapid spontaneous combustion because of its high reactivity and it is not feasible to stockpile char produced from carbonization in fluidized systems.

We have carbonized weakly coking coals, such as the Franklin County Illinois No. 6 coal, and other western bituminous coals in the pilot plant but have found it necessary to oxidize these fuels to prevent troublesome agglomeration and coking on the walls of the reactor and piping. We believe it is quite feasible to carbonize coking coals in the process by circulating char with the fresh coal, but significant experimental work along this line would require operation on a relatively large reactor.

N. E. Sylvander—Mr. Parry and his coauthors deserve our appreciation for this comprehensive report on low-temperature carbonization possibilities with lignite and noncaking coals. The experimental data are complete and in the presented form can be used to evaluate these coals in connection with almost any low-temperature carbonization process. In addition to complimenting the authors on this informative paper, these collateral comments are offered.

Stone, Batchelor, and Johnstone[8] have published quantitative data on the rate of heating and devolatilizing coal particles in a fluid bed. A brief look at these data re-emphasizes the authors' statement that low-cost processing plants can result from the application of fluidized carbonization to coal processing. Stone's paper shows that coal can be heated to carbonization temperatures in about 75 sec. This rapid heating is confirmed by accompanying data which show the devolatilization of the coal approaches equilibrium in that same short period of time. Heating and devolatilization as a function of particle size are briefly discussed, showing that initial devolatilization is much more rapid for the smaller particle size, but that there is little difference after 160 sec.

Correlations of potential tar yield in pilot-scale and plant-scale operations from laboratory assays are most useful. Since the authors' data suggest that the potential yield of primary tar would correlate equally well with the hydrogen content of the coal, it would be interesting to learn whether this possibility has been ruled out by data not shown.

The small-scale assays are compared to the pilot unit yields in Table IX. Here, it is concluded that pilot plant yields are from 1 to 1.3 times the assay yield. Our work with Pittsburgh seam coals indicates that potential yields of primary tar by continuous fluidized carbonization can be 1.3 times the laboratory assay yields. This increase is explained by the rapid heating rate mentioned by the authors, and by the presence of fluidizing gases which sweep the products of carbonization out of the retort.

The pilot plant yields for the first three coals in Table IX may not exceed the assay because of lower pilot plant temperatures. Pilot plant yields for the fourth coal are favored by a temperature in excess of the assay. The sixth coal shows higher pilot plant yields at a temperature below the assay, while the fifth and seventh coals show yields higher than assay at the same temperature. The data are readily acceptable, but some theorizing seems in order.

Earlier in their paper, the authors stated that considerable evidence proved the oxygen in the transport air reacts with the hot char recirculating in the retort without affecting tar yield. This implies, for example, that the tar yields in Table IX for the Danao and Kenilworth coals would be no higher if a heated inert carrier gas were employed with extra heating via the retort walls. Has such a study been made?

The use of a hot electrostatic precipitator has much appeal. The data given indicate efficiencies ranging from 30 to 70 pct. Is there an explanation for this variation?

The report on the prototype plant at Rockdale interests all of us. Appreciation should be expressed for the foresight to initiate this venture and the willingness to solve the difficulties associated with a plant scale-up of this magnitude. The resolution of the fine solids handling problems will be useful to many. The low-temperature tar available from this scale operation calls for new avenues of use. As the authors state, marketing of this new product is a major development in itself. The pioneering spirit of potential consumers should bring about the beginning of profitable industrial ventures and lower power costs from coal in our great Western areas. Is Mr. Parry is a position to make additional comments on carbonization in the near future at Rockdale?

V. F. Parry *(author's reply)*—In a previous paper cited as reference[9] the authors discuss the time required to heat particles of coal to remove inherent moisture. Experimental and theoretical evidence indicates the time required is proportional to the square of the diameter of the particle. Due to the extremely rapid rate of heat absorption of fine coal, it is practically impossible to supply heat to fine particles at a constant temperature level as fast as the particles will absorb the heat. In other words the time required to heat fine particles of coal is limited more by the rate at which heat can be supplied than by the rate at which the particles will accept the heat. From a practical point of view, when the mechanism of heating in a fluidized bed is considered, it is pretty well demonstrated by several investigators that any dry coal of less than ¼ in. can be carbonized in less than 10 min, and this is fast enough to make fluidized carbonization a probable low-cost operation, especially when one considers that it requires about 1000 min to carbonize coal in a coke oven.

We have made no attempt to correlate the yield of tar with the hydrogen content of the coal. However, we have a great amount of data from the assay of several hundred coals, and a study of the correlation of tar yield with hydrogen in the coal will be made.

We are still curious as to why certain coals will yield 10 to 35 pct more tar than that indicated by the assay when carbonized in the pilot plant under similar conditions as to temperature and rate. The reason for the extra yield of tar from certain coals is important from a theoretical and economic point of view. We believe it is tied up with the temperature and rate of carbonization and the difference in petrographic composition of the coals. Another evidence of the difference between carbonization in static and fluid beds is the formation of cenospheres when certain noncoking subbituminous coals are heated rapidly in the fluidized unit.[9] Elkol coal from Lincoln County, Wyo., and Suntrana coal from Alaska fuse, but they do not agglomerate in the fluidized unit and show no fusion when carbonized in the assay unit or other conventional static beds. Although it is generally indicated that 932°F (500°C) is the optimum temperature for maximum tar yield, this may not be true for all coals.

The mechanism of the reaction between air and coal in the reactor has been of continuing interest. Experimental results from pilot plant tests on 30 coals indicate that with low rates of air/coal (those less than 3.5 cu ft of air per lb of dry coal) there is little evidence of reaction of the air with the tar vapors and the yield of tar is approximately the same as the yield when no air is used. We have not studied the effect of different air/coal ratios on the Danao and Kenilworth coals, and our principal studies of the effect of increased air have been on Texas lignites.

With respect to the efficiency of the hot electrostatic precipitator: the efficiency of this section of the condensing equipment depends upon the properties of the coal being carbonized. Certain coals decompose or de-

grade more than others and this places different loads on the precipitator, resulting in various efficiencies. For example, the lignites have no tendency to form cenospheres during carbonization, but certain subbituminous coals and all bituminous coals tested form small cenospheres that are relatively easy to remove before the electrostatic precipitator. The composition of the gases carrying the dust through the precipitator affects the maximum voltage that can be applied, and, consequently, the efficiency.

G. A. Vissac—This is an interesting contribution to the problem of increased returns from a given coal by improved methods of utilization.

However, the final answer must be expressed in dollars and cents. On the Texas lignite, the paper indicates the following results:

Item	Raw Coal	Dried Coal	Char
Moisture	35.6	5.3	0
Ash	9.3	13.7	19.0
Combustible	55.1	81.0	81.0
Btu's	7,156	10,520	10,730
Theoretical recovery		67.88	48.94
less used in dryer (6 pct of 67.88)		4.08	4.08
Net recovery		63.80	44.86

If we assume a value for the raw coal f.o.b. plant of \$1.72 per ton, or 12¢ per million Btu's, the corresponding fuel values of the products are: dried coal, \$2.52 per ton, or \$1.60 per ton of raw coal; char, \$2.57 per ton, or \$1.15 per ton of raw coal.

If we assume a recovery of 18 gal of tars and oils at 6¢ per gal, and operating and capital costs of 20¢ and 40¢ per ton for each product, the balance sheets of these operations indicate for the drying a net loss of 32¢ per ton of raw coal and for the combined drying and carbonization a net profit of 13¢. Actual recoveries, taking all losses into consideration, would still give lower results. Drying alone improves furnace efficiency, but the char is more difficult to burn. Predrying here results in considerable degradation, as shown in Table VI (average size down from 8 to 3) on account of excessive overloading, compared to the German practice (4 to 5 tons per unit against 50 here) and as a result, byproducts may be more difficult to collect.

On the same basis, the balance sheet results show a wider margin with a bituminous coal such as shown, from Utah. On the basis of an f.o.b plant value of \$3.08 for the raw coal the carbonization products are char, \$1.84, and oils, \$2.40. The total of \$4.33 less \$3.08 gives an increased recovery of \$1.25 per ton of raw coal. Drying would not normally be required here.

To be profitable, carbonization costs (capital and operation) must be under \$1.25 per ton of raw coal.

W. S. Landers *(author's reply)*—Mr. Vissac has determined the relative values of raw and dried lignite on the basis of gross heating values instead of from the steam-raising capacities of the raw and net resultant dried lignites. A portion of the water has already been evaporated during the drying process and its heat of vaporization should not be credited to the raw lignite, as is the case when the gross heating value is used. If we assume that the fuels are burned with 30 pct excess air and that the stack gases leave the generating unit at 500°F, the heats available for useful work, neglecting radiation, are as follows:

Item	Raw	Dried	Char
Available heat, Btu per lb	5622	8836	9192
Yield, percent of raw*	100.0	63.3	45.5
Available heat in solid product from one ton of raw, MM Btu	11.24	11.19	8.36
Ratio of available heat in product to available heat in raw lignite	1.00	0.996	0.744

* Net yield, after using 7 pct of product is used to operate the drier.

We have estimated that the cost of drying this lignite will be about 19 cents per ton after charging off the fuel required for drying as above. The total cost of drying, including the loss of available heat, is estimated at 19 to 20 cents per ton of raw lignite, instead of the 32 cents per ton that Mr. Vissac has used.

The value of the tar is not yet established, but various groups are studying this problem. We have recognized that the crude tar must have a sufficiently high value to warrant its production and recovery, and have generally considered that it should sell for more than 6 cents per gallon before the process can be applied economically. This, of course, is a function both of the cost of the coal and the yield of tar. These factors have been evaluated in a recent publication.[10]

Drying does reduce the size of the lignite, as Mr. Vissac points out. This simplifies the utilization when pulverized coal burners are used, but does increase the dust collection problem.

The throughput is higher than in German driers, but this does not necessarily constitute "excessive overloading." Our intent has been to develop a practical drier that will provide the most economical means of drying large tonnages of high moisture fuel. This means maximum utilization of equipment and high capability per dollar invested. The physical size of the product is of minor importance compared to the upgrading of the fuel when it is intended for power plant use.

We have observed no difficulty in burning the relatively high volatile chars obtained by low-temperature carbonization of lignite or subbituminous coals. The reactivity of the low rank coals carries over to the chars. Chars made from bituminous coals or low-volatile higher temperature chars made from the low rank coals present ignition problems. Such chars are not discussed in this paper.

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Discussion

Coal Preparation with the Modern Feldspar Jig

by L. L. Mohier

(MINING ENGINEERING, *page 649, July 1955; AIME Trans., Vol. 202*)

Mr. Vissac's study is very elaborate and complete and gives a clear idea both of phenomena occurring during operation of the feldspar jigs and results obtained by some of them in Europe. I have no intention of going into a complete discussion, but I would like to give a few comments about these results already

obtained and make some comparisons with other washing devices.

Since I intend to compare the various types of units mentioned in Mr. Vissac's article, it will be very convenient for me to use a strict *comparison factor*. For this purpose I will use the *imperfection factor*, mentioned by Mr. Vissac, which was introduced some years ago by Charbonnages de France. This factor is established by the formula

$$I = \frac{E}{d-1}.$$

In this formula E is the well known *probable deviation* (probable error) and d is the separation gravity (or partition density).

I will remind the reader that the result of a coal washing operation depends on several factors: 1) *the nature of the coal*, characterized by its washability curves; 2) *the separation gravity*, or specific gravity at which separation of the products is effected; and 3) *the intrinsic qualities* of the washing device.

The *imperfection* depends almost entirely on the third factor mentioned above: the intrinsic qualities of the washing device. It is a very good *comparison factor* indeed, whereas consideration of the efficiency alone does not show at all the real value of the units. For instance, in Table V presented by Mr. Vissac, we see that the Liévin installation works at 93 pct, whereas the l'Escarpelle plant works at 99.4 pct, *and still the washing units of Liévin are better than those of l'Escarpelle;* in effect we shall see hereafter that the imperfection of the Liévin units is only 0.104, whereas that of l'Escarpelle units is 0.15. In other words, had the Liévin's jigs been installed at l'Escarpelle, the efficiency of this plant would have been higher than 99.4 pct.

Efficiency depends on the shape of the washability curve of the coal treated, and its use to compare two units is definitely erroneous, unless one considers the units treating exactly the same coal. As to the imperfection value, *the smaller it is, the better the unit.*

Having recalled this, I come back to my subject. In Table V Mr. Vissac indicates some probable error figures, which, with respect to the corresponding partition densities, give imperfection values of modern PIC (Préparation Industrielle des Combustibles) feldspar jigs:

Chavane	0.012	0.091
Chavane	0.102	0.11
Liévin	0.105	0.104

Let us consider the other plants mentioned in the same table: 1) As the l'Escarpelle jigs are not PIC jigs, I cannot discuss the figures mentioned, 0.16 and 0.15. 2) For the Sarre et Moselle mine No. 6, the imperfection figures apply to SKB piston jigs (Schuchterman, Kramer, and Baum, Germany) recently converted into PIC pneumatic jigs. Originally the imperfection was 0.19, and now, as one can see, it is only 0.12 and 0.117. 3) At Mazingarbe, the given figures apply to PIC plunger jigs dating from 1938 and tested in 1948. Nowadays Mazingarbe is equipped with PIC pneumatic jigs, with which the operator obtains an imperfection of 0.14.

This shows the headway made in the past few years. It is obvious that the good development of any kind of washing system, and particularly of feldspar jigs, requires much care, patience, and time.

Table VI gives some performances of SKB jigs, characterized by an average I value of 0.19. We do not know the date of the test mentioned.

For the overall 0.7 to 10 mm treated in PIC jigs, section A of Table VIII gives $I = 0.11$ and 0.135 for the first test and $I = 0.13$ and 0.14 for the second test. In section C, for the overall 0.7 to 10 mm also treated in PIC jigs, $I = 0.11$.

Imperfection Values of Other Small Coal Washing Systems: The term *rheolaveurs* is a general heading covering all the alluviation washing units, and we know that there are many types and brands comprised in this general category. According to the report on the activity of the Centre d'Etudes et de Recherches des Charbonnages de France (Cerchar) in 1950, the average imperfection value of the rheolaveurs is 0.20, some of them being characterized by an imperfection value of 0.38.

According to the paper presented by Charbonnages de France at the Washing Congress, Paris 1950, the mean value of imperfection for pneumatic tables is 0.20.

Although wet tables are very little used in Europe, we know some operation results according to which the average imperfection value for wet tables lies between 0.20 and 0.25, some specific values being 0.15 and some others 0.45. Let us mention, on the other hand, what is said in the book *Coal Preparation* concerning wet tables: "It may be stated as a general rule that on an average ¼ in. to 0 raw-coal feed the lowest specific gravity at which tables will make an efficient separation is the one that shows a 10 pct value in the ± 0.10 range."[6]

Section *B* of Mr. Vissac's Table VIII demonstrates that for unclassified raw coal jigs (Baum type), while the coarsest fractions of the feed (+25 mm) are suitably treated, the small coal (0.5x15 mm) is washed with an imperfection of 0.177.

The influence of the imperfection value on the balance sheet of a washing plant will be pointed out by the following instance. We know an installation treating 200 tph of small coal (0x10 mm), the imperfection of which is 0.20. Under the same conditions a device having an imperfection of, say, 0.15 would permit an annual increase of the marketable output of 22,000 tons (at the rate of 20 working hours per day).

The imperfection factor is used not only to compare the various devices as accurately as possible, but also to predetermine, at the time of the proposal, the results the installation will obtain after starting up. Moreover, this method is so precise that predetermined results can be guaranteed. Besides, this method has been extended to other operations such as screening, dedusting, and flotation.

Therefore, we can conclude that this mathematical preoccupation is not a fancy at all, but corresponds really to a need for both constructors and operators. The results given by Mr. Vissac's tables are acceptance results, established at the time of the installation's starting up.

Hourly Capacities of the Units: For several years there has been a tendency to increase the capacity of plants for the treatment of raw coal. We think that such installations can be simple and easy to control only if they are fitted with a minimum number of automatic units having a large unitary capacity. Besides other units (screens, dedusting units, centrifuges, etc.) manufactured by PIC for treating large capacities, the larger size of feldspar jigs, fitted with the highly efficient WOLF automatic controls,[7] may treat up to 400 tph of small coal (½x0 in.).

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aime news

Northeastern Mining Branch Conference

Hotel Hershey, Hershey, Pa. November 8-10, 1956

The Northeastern Mining Branch Conference November 8-10, in Hershey, Pa., has scheduled a well-balanced technical program comprising 15 papers. The AIME Lehigh Valley Section, as host, will welcome registrants to the beautiful Hotel Hershey, site of the conference. A number of social entertainment events and a full program for the ladies is assured. Golf enthusiasts will revel in the splendid green available at the hotel. Field trips include visits to Cornwall Mines and Lebanon Concentrating Plant of Bethlehem Cornwall Corp., Millard Lime & Stone Co., an interesting geology trip and a visit to the famous Charcoal Furnace built in 1743.

W. B. Stephenson is general chairman of the conference and D. S. Lyons, chairman of the Lehigh Valley Section.

Preliminary Program

WEDNESDAY, NOVEMBER 7

1 pm to 5 pm

Registration

THURSDAY, NOVEMBER 8

9 am to 5 pm

Registration

10 am

Mining Branch Council Meeting

11 am **Movie**

12 noon **Welcoming Luncheon**

Guest Speaker—A. F. Peterson, vice president, Mining Div., Bethlehem Steel Co.

2 pm

Technical Session

Mining, Geology and Geophysics

A—The Airborne Magnetometer
Virgil Kauffman, Aero Service Corp.

B—Grace Mine
J. P. Bingham, Bethlehem Cornwall Corp.

C—Marmora Mine
H. O. Olsen, Marmoraton Mining Co. Ltd.

D—Friedensville Mine
Mark Childs, New Jersey Zinc Co.

6 pm

General Open Cocktail Party

(Program continued on page 934)

Rocky Mountain Minerals Conference

The Rocky Mountain Minerals Conference meeting once again in Salt Lake City, September 26-28, will feature a variety of technical sessions and field trips. For full details of the scheduled conference program see August MINING ENGINEERING.

(Continued from page 933)

FRIDAY, NOVEMBER 9

9 am
Technical Session

A—Mining Industry Movie

B—Cornwall Mine
R. G. Peets, Bethlehem Cornwall Corp.

C—Geology & Mining Methods of the Anthracite Region
George Clark, Reading Anthracite Co.

D—Long-Hole Method of Mining of Anthracite
J. J. Crane, G. Lovell and J. Parton

12:15 pm
Mining Branch Luncheon

Guest Speaker—Grover J. Holt, President-Elect, AIME

Ladies' Luncheon and Fashion Show

2 pm
Field Trips (non-conflicting)

2:30 pm
Technical Session—Industrial Minerals

A—The Non-Metallic Industry of Pennsylvania
Carlyle Gray, Pennsylvania Department of Geology

B—Modern Grinding Plant Design in the Cement Industry
W. R. Bendy, W. R. Bendy Co.

C—DeRoll Vertical Cement Kiln
H. H. Hughes, Porter International

D—New York Shipbuilding Co.'s New Graving Dock
J. C. King, Intrusion Prepakt Co.

7 pm
Dinner-Dance

SATURDAY, NOVEMBER 10

9 am
Field Trips (non-conflicting)
Technical Session—Concentration

A—The New Hardinge Disk Roll Mill
E. M. Zuercher and R. J. Russell, The Hardinge Co.

B—Progress Report on the Metallurgical Application of Cyclones
D. D. Melin, Dorr Oliver Co.

C—An Automatic Grinding Control Method
P. L. Steffenson and W. Aubrey, Raw Materials Research Div., Bethlehem Steel Co.

D—Fine Anthracite Coal Beneficiation and Utilization
Hilman Hagen, Consulting Engineer

1 pm
Golf Tournament
Prizes courtesy of Colorado Fuel & Iron Co.

Field Trips

Cornwall Mines and Lebanon Concentrating Plant of Bethlehem Cornwall Corp.
Millard Lime & Stone Co.

Geology Trip

Visit to Charcoal Furnace built in 1743

Ladies Activities

Plant Tour—Hershey Chocolate Co.
Pennsylvania Dutch Museum

Don't Forget!

BRING A QUALIFIED FRIEND TO THE MEMBERSHIP MONTH MEETING IN YOUR SECTION

An outstanding program is planned. Interest him in becoming one of us — He will gain as will our professional society.

OCTOBER IS THE MONTH

—

AIME has become, in effect, an international symbol of all that is good and desirable in an engineering society—and the truth of its incomparable goodness is obvious to mining, metallurgical, and petroleum engineers everywhere.

Send a Contribution Now for Peele Fund

All those who have benefited from the vast store of information given in Peele's *Mining Engineer's Handbook*, and especially those who were students of Prof. Robert Peele when he taught mining at Columbia from 1892 to 1925, are now given the opportunity to contribute to an AIME Award Fund in his name.

The Peele Award, first proposed by the Mining, Geology, and Geophysics Div. of the Institute in 1953, is given to the author or authors, under 40, of the best paper in the mining, geology, or geophysics field published by the Institute over a two-year period. It embraces a cash prize of $100 to each author, a certificate, presented during the Annual Meeting of the Institute, and suitable notice in the *Honors Conferred* booklet distributed at the Annual Banquet, together with other publicity for the recipient.

A Fund of some $10,000 is needed, the income from which will be sufficient to finance an annual award, as contemplated. The Institute, through MGGD, has financed the first two awards, given in 1955 and 1956. However the Board has decreed that, in the future, funds be raised for this specific purpose, as is true of other Institute awards. H. C. Weed, assistant general manager, Inspiration Consolidated Copper Co., Inspiration, Ariz., is chairman of the Peele Award Committee responsible for raising the money and for making the award in 1957.

In addition to honoring a renowned mining engineer, the award provides recognition to authors of papers in the MGG field, similar to the best paper awards in other fields of the Institute. The goal could be met as follows: 5 contributions of $500 each—$2,500; 15 of $100—$1,500; 40 of $50—$2,000; 100 of $25—$2,500; 100 of 10—$1,000; 100 of $5—$500.

The necessary fund can be raised quickly if approximately 400 members of MGG—only a tenth of the AIME members whose primary interest is in the Division—will accept responsibility to the young men of their profession, and pay this tribute to one of the profession's most noted men, to whom all are indebted. Make out a check for whatever you can afford (it is a deductible item on your income tax return, so keep a record of the amount); attach a slip of paper headed *For the Robert Peele Fund* and sign your name; put it in an envelope addressed AIME, 29 W. 39 St., N. Y. 18, N. Y. You will receive an acknowledgment, and the names of contributors will be published in a forthcoming issue of MINING ENGINEERING. Do it now, before you forget!

Fuels Conference Set For October in Capital

Washington, D. C. will be host city for a National Solid Fuels Conference on October 25 and 26. Members of two sponsoring engineering societies, ASME and AIME, and representatives of solid fuels producers and consumers, will meet for two days at the Sheraton Park Hotel to discuss technical and economic developments of importance to the nation. Theme of the conference will be *The Future Role of Solid Fuels in an Expanding Economy*.

Final arrangements are being completed by local members of the two sponsoring societies: Leroy F. Deming, chairman; Louis C. McCabe, co-chairman; C. A. Reed, C. F. Hardy, William L. Crentz, R. E. Jack, William Bradbury and Mrs. A. Wiley Sherwood. Mr. Deming, general chairman of the conference, is head of the power generation section, Bureau of Yards and Docks, U. S. Navy, Washington, D. C. He is serving as chairman in place of Louis R. Caplan who is ill.

More than 400 engineers, guests and ladies are expected to attend the event. Special sight-seeing tours and social events have been arranged for the ladies. Additional attractions are being planned for visitors who stay through the weekend following the conference.

Engineering Societies Personnel Service Inc., held its first joint meeting of the Board of Directors and branch office managers, July 23-24, at the Engineering Societies Building, N.Y.C. Their discussion of ways to meet the changing employment conditions resulted in several important ESPS national policy changes. Pictured at the meeting, left to right, standing; R. Gardner, AIEE; B. Allen, Chicago Manager; G. Parker, N. Y. Manager; J. Decker, San Francisco Manager; O. B. Schier II, ASME; E. J. Kennedy, AIME; P. Apol, AIME; J. A. Zecca, ASCE; E. Hartford, ASME; F. McKinless, Detroit Manager. Seated: E. Kirkendall, AIME Secretary; C. E. Davies, ASME Secretary; N. Hibshman, AIEE Secretary; A. H. Meyer, ESPS Executive Director; and W. Wisely, ASCE Secretary.

ANNUAL MEETING

Plans for the 1957 AIME Annual Meeting are progressing nicely. Scheduled for February 24-28, at the Roosevelt and Jung Hotels in New Orleans, the meeting will feature technical sessions and symposiums as well as luncheons and a banquet. Members who plan to attend should make arrangements early. For details and registration blank see p. 836A, August MINING ENGINEERING.

Herbert Hoover, Jr. To Receive Hoover Medal

The Hoover Medal for 1956, one of the engineering profession's highest awards, will be presented to Under Secretary of State Herbert Hoover, Jr. Named after former President Hoover, father of the Under Secretary, and in 1930, its first recipient, it is awarded each year by the four sponsoring engineering societies, AIME, ASCE, ASME, and AIEE, "to a fellow engineer for distinguished public service."

Scott Turner, chairman of the Hoover Medal Board of Award, announced the choice. The board consists of three representatives from each of the four sponsoring organizations. Dr. Turner is a Past President of AIME and a former director of the U. S. Bureau of Mines. Time and place of the presentation will be announced later. The ceremony will be under direct sponsorship of AIME, of which the winner has been a member since 1937. Former President Hoover, a member since 1896, is AIME Senior Past President, having held office in 1920. The Board of Directors in 1917 elected him an Honorary Member, highest AIME distinction and in 1928 he was the recipient of the William Lawrence Saunders Gold Medal.

This is the first time in the Institute's 86 years that there has been a father and son achievement of so high an award. The younger Hoover, a graduate of Stanford University, received an M.A. from Harvard in 1928, and had a teaching fellowship at California Institute of Technology, of which he later became a Trustee.

Mr. Hoover, Jr., assumed the presidency of Geophysical Corp., Pasadena, Calif. in 1935 and later became chairman of the board. However, he left his business interests to undertake assignments in foreign relations which led to his appointment as Under Secretary of State. He has contributed to AIME technical papers on geophysics, and is a member of the American Assn. of Petroleum Geologists and the Society of Exploration Geophysicists.

Around the Sections

• Robert Walter Helfer was this year's winner of the Old Timers Club watch award at Pennsylvania State University. After receiving his B.S. degree in mining engineering in June, Mr. Helfer started work as a coal mine engineer for the Seanor Coal Co. The watch was presented to Mr. Helfer by S. M. Cassidy, vice president, Pittsburgh Consolidation Coal Co., at a banquet held on May 23 in the Hetzel Union Building.

• The **Florida Section** made a field trip on June 9. The group met in Pierce, and went on a guided tour of the elemental phosphorus plant of American Agricultural Chemical Co. and the triple superphosphate plant of Davison Chemical Co.

Local Section Changes

Petroleum Branch members in Duchesne and Uintah Counties, Utah, are now included in the area of the **Denver Petroleum Section** whose new Uintah Basin Subsection now includes, besides the two counties named, the following counties in Colorado: Garfield, Mesa, Moffat, Rio Blanco, and Routt.

A part of the territory of the **Kansas Section** has been assigned to a new Local Section to be known as the **Great Bend Local Section.** It comprises the following Kansas counties: Ellsworth, Rice, Barton, Stafford, Pratt, Kiowa, Edwards, Hodgeman, Pawnee, Ness, Rush, Trego, Ellis, Russell, Rooks, Graham, Gove, Sheridan, Norton, Phillips, Cheyenne, Rawlins, Decatur, Sherman, Thomas, Wallace, Logan, and Lane.

In Venezuela, the **Venezuela Petroleum Section** has released some of its territory to the new **Western Venezuela Petroleum Section.** Its area includes the following states: Zulia, Tachira, Merida, Trujillo, Lara, Falcon, Yaracuy, Portuguesa, Cojedos, Barinas, and Apure.

• AIME President, Carl E. Reistle, Jr., visited the **Colorado Plateau Section** at Grand Junction, Colo., on May 22, accompanied by R. E. O'Brien, AIME Field Secretary. After attending an informal luncheon with officers and directors of the Section, and representatives of the uranium industry, Mr. Reistle visited the sampling and assaying installations of Lucius Pitkin Inc., and the pilot plant installation of National Lead Co. at the U. S. Atomic Energy Commission compound. In the evening Mr. Reistle addressed the 60 members and guests at a dinner given in his honor at the Redlands Club.

• The **San Francisco Section** held a dinner meeting at the Engineers Club in May. Featured speakers were Durand Hall and George I. Barnett, who discussed the problems of the independent mine operator. They own and operate the Castro Mining Co., one of California's most important producers of chrome concentrates.

• The **El Paso Metals Section** met on May 24 at the Hotel Cortez. The principal speaker was AIME President, Carl E. Reistle, Jr.

• The Annual Meeting of the **Lima, Peru Section** was held on July 21. The section celebrated its Fourth Anniversary with a cocktail-dinner-dance at the Lima Country Club. The new chairman of the section, Arthur C. Hall, vice president, Southern Peru Copper Corp., introduced the guest of honor, Hector Boza, First Vice President of Peru, who is also a member of AIME. Speaking for the AIME Woman's Auxiliary was their chairman Mrs. Julian D. Smith. During the evening a raffle was held, the funds to be used for an educational grant. Entertainment included a professional dance team.

Three industrial films are now available at no cost, from Christensen Diamond Products Co. Offered for showings at association meetings or conventions, these films are all 16 mm. color with sound and average 25 min. Any one film or all three, may be obtained.

Film 1 deals with diamond production in South Africa and shows how diamonds are recovered from the famous Kimberly Mine and from alluvial deposits. Of special interest to those who have seen or used diamond bits in the field, Film 2 shows how these bits and barrels are manufactured. Through the eye of the camera, the viewer takes a brief tour of the Christensen plant in Salt Lake City.

Film 3 shows the application of diamond products and their use in the petroleum, mining, and construction industries. Address requests for these films to: Christensen Diamond Products Co., P. O. Box 387, Salt Lake City 10, Utah. In the event of any duplication in requests, the parties concerned will be advised and arrangements made for rescheduling.

More than 20 films made by Allegheny Ludlum Steel Corp. are available for showing at regional meetings. Most of the movies are in color and all prints are 16 mm with sound. There are general films as well as technical movies on such subjects as the making of stainless steel. A revised list of the films has been published and may be obtained by writing to the company's Advertising Dept., 2020 Oliver Bldg., Pittsburgh 22, Pa.

The 1956 National Directory of Safety Films is now available. It describes more than 1200 films, and includes information on millimeter, running time, and year produced. A copy of the directory can be purchased for $1.00 from the National Safety Council, 425 N. Michigan Ave., Chicago, 11.

The Student Story

(by a member of the St. Louis Local Section)

Realizing that students in the mineral industries are our source of engineers, management personnel, and our big hope for future membership, this section is striving to assist them in their studies, contacts, and finances.

The St. Louis Section of the AIME has under its wing, the student chapters of six schools. These are at St. Louis University; Washington University, St. Louis; University of Missouri, Columbia, Mo.; Missouri School of Mines and Metallurgy, Rolla, Mo.; University of Illinois, Urbana; and Iowa State College, Ames, Iowa.

In the past we have held a special annual program, Student's Conclave, which failed to attract enough regular members. This year we are coaxing students to attend our regular sessions by paying half the cost of their dinner. The effect has been a small but encouraging trickle of students, chiefly from our two schools in St. Louis.

To help those from more distant locations, we invite students from each school to attend one meeting during the year with all expenses paid, including transportation. This results in fairly good attendance by student members.

(continued on page 944)

PERSONALS

Donald B. Gillies has retired as mining consultant for Republic Steel Corp. after 50 years of service. Prior to his 75th birthday in 1947, Mr. Gillies was vice president at Republic. A native of Ontario, Canada, he received his B.S. and E.M. degrees from Michigan College of Mining and Technology at Houghton. Mr. Gillies managed the Mexican mining properties of Corrigan, McKinney & Co. which later became Republic Steel. His contributions to the company include developing the iron ore in the Northern Adirondacks and Liberia; he also was instrumental in exploring a titanium-bearing ore in southern Mexico. A past-president of AIME, and Lake Superior Iron Ore Assn., Mr. Gillies is a member of the Mining and Metallurgical Society of America. He has been honored by his alma mater with a Doctorate in Engineering, and by Montana School of Mines with a D.S. degree.

W. C. CLARK

William C. Clark, formerly mine superintendent at Santa Barbara, Mexico, is now assistant manager, Quiruvilca Unit, Northern Peru Mining Corp., Trujillo, Peru.

Ko Suzuki has gone to Japan, and is now with the mining dept., Faculty of Engineering, University of Tokyo, Bunkyo-ku, Tokyo.

Harry J. Wolf, mining and consulting engineer of New York, recently completed an investigation of tungsten resources of Boulder County, Colo. Mr. Wolf also made an examination of the non-metallic mineral deposits in the Carolinas, and several uranium properties in Utah and adjacent states.

Robert B. Mahan is general superintendent, Philippine Iron Mines Inc., Larap, Jose Pañganiban, Camarines Norte, P.I. Mr. Mahan was with Baguio Gold Mining Co., Baguio City, P.I.

Max C. Scheble is assistant to the general manager, operations, Columbia-Geneva Steel Div., U. S. Steel Corp., San Francisco, Calif. Mr. Scheble was superintendent of stone quarries, Geneva Steel Co., Provo, Utah.

Denis John Bobka has joined Teletype Corp., Chicago, as contract engineer. Mr. Bobka was with Timken Roller Bearing Co., Spokane.

Virgil R. Huff is supervisor of plans, U. S. Steel Corp., Pittsburgh. Mr. Huff was with the Oliver Iron Mining Co., Coleraine, Minn.

J. C. O'Donnell, formerly mine superintendent, Tungsten Mining Corp., Henderson, N.C., is sales engineer, Shaft & Development Co., Salt Lake City.

W. S. Adams, assistant mill superintendent, Opemiska Copper Mines in Quebec, is with Maritimes Mining Co., Tilt Cove, Newfoundland.

R. R. Williams, Jr., manager, Mining Dept., Colorado Fuel & Iron Corp., Pueblo, Colo., has been appointed a member of a 15-man industry committee to advise the Office of Minerals Mobilization on ore production. **Spencer S. Shannon, Jr.,** director of the Office of Minerals Mobilization, will be the chairman of the committee.

George Hellerich has joined W. W. Johnson Co. of San Francisco, as a mining engineer.

Felice C. Jaffé is with Newmont Mining Corp., New York. Mr. Jaffé was with Clark M. Robertson in Milwaukee.

Donald C. Stevens has left Australia and is now in Canada working for Gunnar Mines Ltd., Uranium City, Saskatchewan. Mr. Stevens was formerly with Zinc Corp. Ltd., Broken Hill, New South Wales.

F. A. McGonigle has joined Haile Mines Inc., New York. Mr. McGonigle was with Manganese Inc., Henderson, Nev.

Merle H. Guise, exploration engineer of Yonkers, N. Y., has returned to the U. S. from a trip around the world.

I. M. Hossy has been appointed consulting engineer to Permanent Gypsum & Allied Industries in Cape Province, South Africa.

Howard Evans, mineral processing engineer, Oliver Iron Mining Div., U. S. Steel Corp., Duluth, has been appointed supervisor, beneficiation laboratory at U. S. Steel's Columbia Iron Mining Co., Cedar City, Utah. Mr. Evans joined the Oliver Iron Mining Div. shortly after graduating from the University of Minnesota in 1947. For several years he has been chairman of the membership committee, AIME Minnesota Section.

James Boyd is vice president, exploration, Kennecott Copper Corp., New York.

Norman J. Sather, formerly mill superintendent, Hecla Mining Co., Wallace, Idaho, is now superintendent of concentration, The Bunker Hill Co., Kellogg, Idaho.

Frank L. Simonson is process engineer, Reynolds Metals Co., Patterson plant, Arkadelphia, Ark.

Warren Fuchs, formerly engineer, Chemical Construction Corp., New York, is now in Tel Aviv, Israel.

Jerome J. Daly is mining engineer, Fluorspar Div., Minerva Oil Co., Eldorado, Ill. Mr. Daly was formerly with Atlas Diesel Corp. in New York. **William Rule** is metallurgist at Minerva's Mine No. 1 mill, Cave-In-Rock, Ill. Mr. Rule was with the Tennessee Copper Corp., Ducktown, Tenn.

William Zilbersher has joined the New York staff of Ventures Ltd. Mr. Zilbersher was chief geologist, Crane Co., Chicago.

Charles C. Hilton is now industrial relations manager, U. S. Smelting, Refining & Mining Co., Salt Lake City.

Thomas Q. Morris, formerly with Bruhi Mining Co., Silver Peak, Nev., has joined Getchell Mines Inc., Golconda, Nev.

William C. Schmidt and **Neil A. O'Donnell** have opened an office as mining consultants under the name of O'Donnell & Schmidt at 165 Broadway, New York 6.

R. M. FOOSE

Richard M. Foose, chairman, Dept. of Geology, Franklin and Marshall College, Lancaster, Pa., has been named as one of the two AIME delegates to the 20th International Geological Congress meeting in Mexico, September 4 to 11. Mr. Foose has also been appointed delegate to the Congress for the Assn. of Geology Teachers. During June and July Mr. Foose will be mapping in the Beartooth Mountains, Mont., under a National Science Foundation grant.

William O. Brandt is vice president, Procosa Industries, Monterrey, Nuevo Leon, Mexico. Mr. Brandt was ceramic engineer and director of research and development, Gladding McBean & Co., Los Angeles.

Verne D. Johnston is now a consultant, specializing in estimates of reserves, their occurrence, qualities and markets, and mine evaluation. His address is: 14921 Lake Ave., Lakewood 7, Ohio. Mr. Johnston was formerly with Oglebay, Norton & Co., Cleveland, and had worked with that company since 1918.

Gill Montgomery, general manager, Fluorspar Div., Minerva Oil Co., Eldorado, Ill., since 1952, has been promoted to the position of vice president in charge of the company's Fluorspar Div.

Edward L. Wemple is a partner in the firm of Coverdale & Colpitts, consulting engineers, 120 Wall Street, New York.

A. Roy Reed, formerly mine superintendent, Lepanto Consolidated Mining Co., Mankayan, P.I., has returned to the Philippines after making a trip round the world. Mr. Reed is now with Botolan Copper Co., Inc., Botolan, Zambales.

W. H. Breeding has been appointed assistant vice president, South American Gold & Platinum Co., New York. Mr. Breeding was with Pato Consolidated Gold Dredging Ltd., Pato Antioquia, Colombia.

Ennis A. Naeve has joined Vogt, Ivers, Seaman & Assoc., Cincinnati.

John D. Hess has opened offices in El Centro, Calif., as a consulting ground-water geologist. In addition to general ground-water problems, Mr. Hess will serve the fields of geochemical interpretation of waters and drainage. Mr. Hess will be assisted by **Ellsworth Shaw** in the chemistry phase as applied to agricultural waters. Mr. Hess is also director of Valley Analytical & Testing Laboratories Inc. in El Centro. He was formerly with the U. S. Bureau of Reclamation.

Allan M. Short is head of the geological section, Directorate of Petroleum and Mineral Affairs, Ministry of Finance, Jeddah, Saudi Arabia.

W. H. H. Cranmer, president, New Park Mining Co., Keetley, Utah, has been elected a director of the Lead Industries Assn.

John Trumbull Lindquist is sales representative, Explosives Dept., E. I. du Pont de Nemours & Co. Inc., Seattle. Mr. Lindquist was with the Empire Zinc Div., New Jersey Zinc Co., Gilman, Colo.

Angus D. Campbell, staff engineer, McIntyre Porcupine Mines, Schumacher, Ont., has retired from active mining and is residing in Toronto.

Elza Fain Burch is assistant director of preparation, Island Creek Coal Co., Holden, W. Va.

Charles E. Lawall has been appointed vice president, coal traffic and development, Chesapeake & Ohio Ry. Mr. Lawall joined C&O in 1945 as engineer of coal properties. Prior to that he was president of West Virginia University, Morgantown. Mr. Lawall is also chairman of the Mining Development Committee of Bituminous Coal Research Inc. He was secretary of the West Virginia Coal Mining Institute for ten years, and is a past president of that Institute.

John C. Russell is metallurgical engineer, Singmaster & Breyer, New York. Mr. Russell was with Rhoanglo Mine Service Ltd., Kitwe, Northern Rhodesia.

Edward H. Snyder, president, Combined Metals Reduction Co., Salt Lake City, has been elected vice president and a director of the American Zinc Institute.

Walter E. Heinrichs, Jr., is manager, Minerals Exploration Co., Tucson, Ariz. Mr. Heinrichs was exploration engineer, United Geophysical Co. Inc., Tucson.

Kenneth D. Lair, pit engineer, Ray Mines Div., Kennecott Copper Corp., is now development engineer at the Ray plant. Mr. Lair joined Kennecott in 1953 soon after he graduated from Oregon State College. He succeeds **Rene F. Kast** who has resigned to take a position with the exploratory drilling unit of the Tucson Regional office, American Smelting & Refining Co. Mr. Kast had been with Kennecott since 1949. In 1952 he presented a paper on roof-bolting practices and studies in the underground section of the Ray Mine to a Tucson meeting of the AIME.

Leroy K. Wheelock has left C. Tennant, Sons & Co. of New York and is now with the Engineers Joint Council, New York.

Hugh D. Graham has returned to the U.S. and is now in Erie, Colo. Mr. Graham was with the USBM in Kabul, Afghanistan.

JOHN J. THEILER

John J. Theiler is now a mining engineer with Inspiration Consolidated Copper Co., Inspiration, Ariz. Mr. Theiler was with Tri-State Zinc Inc., Galena, Ill.

Darl A. Moyer is now a partner in the Mamoy Mining Co., Route 3, Box 895, Glendale, Ariz. Mr. Moyer was formerly with the Surcease Mining Co., Red Mountain, Calif.

D. W. Fuerstenau has left Massachusetts Institute of Technology and the teaching profession. Mr. Fuerstenau has taken a job in industrial research with the Metals Research Laboratories, Electro Metallurgical Co., Niagara Falls, N. Y.

W. Krenning, mine engineer, Cie "Corem", Kigali, Ruanda-Urundi, Africa, has returned to Holland.

Godfrey B. Walker is now a consulting engineer at 37 Lockwood Drive, Old Greenwich, Conn. Mr. Walker was with American Cyanamid Co., Stamford, Conn.

Andrew J. Gaber has joined United Electric Coal Co., Chicago. Mr. Gaber was with Mather Collieries, Mather, Pa.

Arthur C. Thompson is geologist with Union Carbide Nuclear Co. at Bishop, Calif.

Robert Schoen has rejoined the Atomic Energy Commission, Grand Junction, Colo., as a geologist, after two years surveying for the Corps of Engineers in Okinawa, Japan, and in Thailand.

G. F. Metz has retired from the positions of Eastern District manager and supervisor of sales promotion, Hardinge Co. He had been with the company for 36 years. Mr. Metz will be doing a limited amount of consulting work in the field of nonmetallic mineral processing. His address is: 816 Cypress Road, Vero Beach, Fla.

Clinton L. Milliken, formerly with Hirsch Bros. Machinery Co., El Paso, Texas, is senior mechanical design engineer, Kaiser Engineers, Oakland, Calif.

Frank C. Pickard is mining consultant for the American Metal Co. Ltd., Grants, N. M.

Roderick G. McDonald has joined National Gypsum Co., Kimballton, Va., as mining engineer. Mr. McDonald was with the Oliver Iron Mining Div., U. S. Steel Corp., Hibbing, Minn.

C. W. Archibald is manager, Invex Corp. Ltd., Toronto. Mr. Archibald was mine engineer, St. John d'el Rey Mining Co., Minas Gerais, Brazil.

Antonio Chavez has joined Kaiser Gypsum Co. Inc., Oakland, Calif., as mine engineer. Mr. Chavez was with Cía. Occidental Mexicana, Santa Rosalia, Mexico.

David L. Starbuck is sales manager, Mercury Piping Co., Norwood, Mass.

Fred Kienzle is project engineer, Cerro de Pasco Corp., New York. Mr. Kienzle was with Chile Exploration Co., Chuquicamata, Chile.

William D. Stark is industrial engineer, Jewell Ridge Coal Corp., Logan, W. Va.

Harry G. Gerber is superintendent, The Hilton Mines, Shawville, Que. Mr. Gerber was general plant foreman, Erie Mining Co., Hibbing, Minn.

J. Lanigan is with Cerro de Pasco Corp., La Oroya, Peru. Mr. Lanigan was with Chile Exploration Co. in Chuquicamata, Chile.

Robert B. Williamson, vice president, Pittston Clinchfield Coal Sales Corp., Cleveland, is now president, Lillybrook Coal Co., Lillybrook, W. Va.

Paul I. Eimon has returned to the staff of the American Smelting & Refining Co., with headquarters at the company's Eastern U. S. Div., Knoxville, Tenn. Mr. Eimon was formerly associated with the Dept. of Geology, University of California, at Berkeley.

M. C. IRANI

M. C. Irani has been appointed vice president of research and development of the metals chloride division, Salem-Brosius Inc., Pittsburgh. Mr. Irani had been a member of the research foundation, Colorado School of Mines. Prior to accepting his new post, he had been associated with Julius Hyman & Co., Denver, and Booth Engineers, Salt Lake City. In his new capacity, Mr. Irani will deal with the development of applications for the division's new high temperature chlorinating furnaces. His published works include: *Thorium as a Source of Atomic Power.* Mr. Irani is a member of the American Chemical Society and AIME.

A. M. Thomas has returned to England. Mr. Thomas was with the St. John d'el Rey Mining Co. Ltd., in Brazil.

Gordon L. Bush is with American Overseas Petroleum Ltd., Gaziantep, Turkey.

Edwin F. Atkinson is test engineer, Planning Dept., Climax Molybdenum Co., Climax, Colo. Mr. Atkinson was with Homestake Gold Mines, Lead, S. D.

Gerhard Grassmueck has resigned as production engineer, Lamaque Mining Co. Ltd., Bourlamaque, Que. Mr. Grassmueck is now with Incomi S.A., Buenos Aires, Argentina.

J. S. Livermore has joined Newmont Mining Corp., New York. Mr. Livermore was with Resurrection Mining Co., Leadville, Colo.

Wendell W. Fertig, mining engineer consultant at C. A. Johnson Building, Denver, Colo., is now connected with Ball Associates of Washington and Denver.

Stanley Ruby is physical chemist, Avco Mfg. Corp., Stratford, Conn.

Edward P. Kyburz, recently discharged from the Army's Corps of Engineers with service at Ft. Belvoir and in Germany, has joined the staff of American Smelting & Refining Co.'s Silver Bell Unit, Silver Bell, Ariz.

George S. Koch, Jr., formerly with San Francisco Mines of Mexico Ltd., is now at the Dept. of Geology, Oregon State College, Corvallis, Ore.

Alvin J. Thuli, Jr. has been appointed assistant chief engineer, Utah Copper Div., Kennecott Copper Corp. He joind Kennecott in 1954 as assistant to the chief engineer, Western Mining Div. Mr. Thuli is assistant general chairman of the Rocky Mountain Minerals Conference, Sept. 26-28 in Salt Lake City.

V. D. Perry, chief geologist, the Anaconda Co., is moving the headquarters of the geological department from Salt Lake City to 25 Broadway, N.Y.C. **Roland B. Mulchay** has been transferred to Salt Lake City as assistant chief geologist where he will have charge of the company's operations in Mexico and Western U. S. **James L. Kelly** has been named to head the exploration office in Tucson Ariz., where he will be in charge of Anaconda operations for Southwestern U. S.

Charles E. Johnston, mining and project engineer, Food Machinery & Chemical Corp., Grants, N. M., is now mine superintendent, Grand Rapids Plaster Co., Grand Rapids.

Howard Wilmeth is mine engineer, Chino Mines Div., Kennecott Copper Co., Hurley, N.M. Mr. Wilmeth joined Kennecott in 1950 as a transitman at the Chino properties. After graduating from the New Mexico Institute of Mining and Technology at Socorro, he spent three years with The Anaconda Co. at Portrerillos, Chile.

Raymond E. Johnson has joined Erie Mining Co., Aurora, Minn., as mining engineer.

E. C. Young has joined Rhoanglo Mine Services Ltd., Kitwe, Northern Rhodesia, as pilot plant supervisor in the Research and Development Div. Mr. Young was general manager, Kyerwa Syndicate Ltd., Uganda, British East Africa.

Raymond C. Troxell is metallurgical engineer, American Smelting and Refining Co., Salt Lake City. Mr. Troxell was formerly at the Research Laboratories, Aluminum Co. of America in East St. Louis.

William A. Palmer is mine superintendent, Holly Minerals Corp. in Grants, N. M. Mr. Palmer was with International Ranwick Ltd., Cortez, Colo.

E. P. Flint has resigned as director, Inorganic Research, Mallinckrodt Chemical Works, St. Louis, and has joined the senior staff of Arthur D. Little Inc., Cambridge, Mass.

Jackling Will Designates AIME to Receive $150,000

Former AIME President Daniel C. Jackling, who died March 13, 1956 at the age of 86, has bequeathed a total of $150,000 to the AIME; $50,000 to be used for scholarships, $75,000 for a new building "in New York", and $25,000 for the Woman's Auxiliary Educational Fund. It has been estimated that the amounts of these bequests may be increased many times when the funds become available; in the meantime a trusteeship has been set up during Mrs. Jackling's lifetime.

Mr. Jackling left an estate valued at several million dollars, most of which will go to educational institutions, churches, and scientific societies. Other substantial bequests included: $500,000 to Mrs. Jackling; some $400,000 to relatives, friends and employees; $100,000 to the University of Missouri; $50,000 to Stanford and to the Red Cross; $75,000 each to the Boy Scouts and Girl Scouts; and $100,000 to the Mormon Church.

October 1 Deadline For Nuclear Congress Papers

The Second Annual Nuclear Science and Engineering Congress will be held at Convention Hall, Philadelphia, March 10-15, 1957. The Congress is under the sponsorship of Engineers Joint Council. The papers to be presented will cover all aspects of the field.

October 1 is the deadline for receipt of papers, which should be submitted in three copies.

In order to facilitate planning of technical sessions, prospective authors are requested to advise Frank Rough, AIME representative on the EJC Program Committee, of their willingness to participate. The title of the paper and a brief summary, or outline of its contents should be sent immediately to: Mr. Frank Rough, Battelle Memorial Institute, 505 King Avenue, Columbus 1, Ohio.

The Student Story

(continued from page 938)

It seems that a standing offer of a free meal and about $2 per student per 100 miles distance, would afford sufficient financial support to those wishing to come. We believe the habit of attending meetings should be established early. Funds for this endeavor should come from those who will benefit by this association, such as companies who work with minerals and their products, and our Institute, which will provide itself with a new source of interested, *active* members.

Those who should pay are the companies and the local sections. The companies come first, because they may be able to secure money more easily. Then too, it should be a deductible expense, and also they benefit the most. In fact, the companies in the area served by each local section, and by each school which the local section serves, ought properly to contribute to a special fund for this purpose.

In the St. Louis Section we do have such a fund, managed by the local executive committee. It might prove more flexible if handled by a subcommittee devoted to improving relations with student associates. One or two members might be elected or appointed to the executive committee to function on this subcommittee.

This year serious consideration was given to underwriting the expenses of students wishing to attend the national meeting. One of the difficulties was the selection of students, and therefore, this part of the program did not get under way. Probably if we put up $300 annually, it could be divided among the schools and distributed equally among all the students who could make the trip.

The choice of students could be left to the student chapters. Although there is no intention of making this help a reward for scholarship, the faculty should assure us that students selected have maintained adequate grades.

Regarding prizes, no section is rich enough to endorse large scholarships although some do assist promising students with small cash awards. Our section as yet has no program of this kind. One of our former members, J. H. Steinmesch, gave cash prizes for the three best papers pertaining to the mineral industries. Since his death in 1954, this award, named for the original sponsor, has been made through the generosity of Robert Gill Montgomery. If the standard of excellence continues to be as high as it has been, the award might well become one of the most coveted marks of professional attainment for students. Our Institute, through its local sections, should guarantee the future of awards begun, since they so obviously benefit the profession.

Although we could not organize any help this year, we are proud to announce that three students from the Missouri School of Mines, attended the Annual Meeting, February, in N. Y. and have received several job offers from people they met there. Welcome to Harlan Kebel, Harold Staves, and Michael Vallez, all mining engineers.—*Professor Bob.*

OBITUARIES

Joseph Adams Inslee

An Appreciation by

Percy A. Seibert

On Dec. 20, 1955, at his home in Key West, Fla., Joseph Adams Inslee died of complications caused by many years of professional work in Bolivia at altitudes ranging from 11,500 to 17,000 ft above sea level.

In 1905, on finishing his civil engineering course at Yale University, where he was an outstanding oarsman and varsity team football player, he became engaged in railway surveys and construction in Mexico, then in bridge building in Guatemala, and briefly on the Panama Canal. At the age of 25, he joined the engineering staff of the Bolivia Railway Co., and on its curtailing activities during the depression which followed the 1907 financial panic, he joined the Andes Tin Co. at its Concordia mines, in Ichoca Canton, Inquisive Province, Bolivia, of which company he became assistant general manager in 1910. In 1914 he formed a partnership with James Patrick Ahern, and for some years they operated the Concordia mines under lease. Then he and George A. Easley organized the partnership of Easley & Inslee and for many years they financed and operated tin, wolfram, lead, and zinc properties in Bolivia and exported those metals. For some time he was operating

general manager of Patiño Mines & Enterprises Consolidated Ltd. Thereafter he became associated with the Montreal Engineering Co., which entity appointed him general manager of its subsidiary, Bolivian Power Co., a position which he filled with distinction and to the satisfaction of the company, the government, and the Bolivian public. His name became a synonym for integrity and high ethical standards. In gratitude for his valuable services in the public interest of Bolivia and by virtue of the high esteem in which he was held by all, the Supreme Government of Bolivia made him a Knight Commander of the Order of the Condor of the Andes.

He was born in St. Louis, the son of John A. Inslee, a lawyer, who was at one time general manager of the Wabash Railroad. He is survived by his widow, Lucille Inslee, daughters Betty Ann and Leila, and son John A. Inslee II, an outstanding chemical research engineer with the Radio Corp. of America.

Frank F. McLaughlin (Member 1938) died March 26, 1956 at his home in San Diego, Calif. He was born in St. Louis on September 23, 1890, and attended Transylvania University in Lexington, Ky. Mr. McLaughlin did consulting work in connection with drilling and blasting limestone quarries. A production engineer, he was general superintendent, General Crushed Stone Co., Easton, Pa., and also worked for the France Stone Co., Toledo. He later worked as mining engineer in Panama and the Canal Zone. Mr. McLaughlin served as pastor of the Methodist Episcopal Church from 1915-1918.

Archer E. Wheeler (Legion of Honor Member 1899) died Apr. 8, 1956. Mr. Wheeler, who retired in 1947, was a consulting metallurgical engineer in New York City. He was born in Auburn, Maine, in 1868. After completing a special 3-year course at Massachusetts Institute of Technology, Mr. Wheeler worked for Boston & Montana Consolidated Copper & Silver Mining Co., Great Falls, Mont. Later he joined the firm of Robert Williams & Co. in London, England. In 1917 he returned to New York and went into private practice.

Laurance I. Neale (Member 1914) died Mar. 31, 1956. Mr. Neale was a Minister at The Unitarian Church of All Souls, Lexington Ave., New York. He was born in Boston in 1885. After graduating from Harvard University in 1906 he was employed by George A. Fuller & Co., and later by J. B. King & Co., New York. In 1924 he joined U. S. Gypsum Co., where he organized and managed two new departments. From 1927 to 1936 Mr. Neale was with Atlantic Gypsum Products Co., New York. He was vice president and a director of the Gypsum Assn. from 1929 to 1936.

William B. Plank (Member 1919) died on June 19, 1956, of a heart attack, in his home in Morgantown, Pa., where he was born 70 years ago. He received a B.S. and M.S. degree at the University of Pennsylvania and in 1920 joined the faculty of Lafayette University, Easton, Pa., where he remained for 32 years. Prof. Plank founded the Dept. of Mining and Metallurgical Engineering, becoming the first to head it, and also helped establish the Faculty Club. In addition to his work in the academic field, Professor Plank was consulting engineer to several national firms, and to the U. S. Coal Commission and the Emergency Fuel Commission. He also was a mining engineer for the USBM. During World War II he was coordinator of an Army Ordnance Research Project and was honored by the Army Dept. in 1951 for his work as London representative for the Technical Industrial Intelligence Committee of the U. S. Joint Chiefs of Staff. Since his retirement as Professor Emeritus he had been lecturing and wrote several books, in addition to articles, some of which have appeared in JOURNAL OF METALS and MINING ENGINEERING. Past-chairman of the AIME Lehigh Valley Section, he was also a member of the Coal Mining Institute, Engineers Club, and president and founder of the Morgantown Rotary Club.

Necrology

Date Elected	Name	Date of Death
1929	Walter M. Briggs	Unknown
1906	W. R. Dunn	Unknown
1955	William M. Frailey	Mar. 10, 1956
1918	Oscar E. Harder	July 10, 1956
1928	Erle G. Hill	July 26, 1956
1951	Rudolph M. Lombardi	May 12, 1956
1944	James D. McClintock	July 2, 1956
1916	A. J. McNab	July 4, 1956
1928	A. H. Pogson (Rocky Mountain Member)	Unknown
1947	Charles H. Snelson	Unknown

MEMBERSHIP

Proposed for Membership
Mining Branch, AIME

Total AIME membership on July 31, 1956 was 25,255; in addition 2,795 Student Associates were enrolled.

ADMISSIONS COMMITTEE

R. B. Caples, Chairman; F. A. Ayer, Vice-Chairman; A. C. Brinker, R. H. Dickson, C. R. Dodson, R. B. Fulton, T. D. Jones, F. W. Hanson, Sidney Rolle, F. T. Sisco, O. B. J. Fraser, F. W. McQuiston, Jr., A. R. Lytle, L. P. Warriner.

The Institute desires to extend its privileges to every person to whom it can be of service, but does not desire as members persons who are unqualified. Institute members are urged to review this list as soon as possible and immediately to inform the Secretary's office if names of people are found who are known to be unqualified for AIME membership.

Members

Luis H. Aguirre, Kansas City
Edward W. Crowe, Guatemala City, Guatemala
Claude L. Holloway, Jr., Fairfield, Ala.
Robert E. Jones, Knoxville, Tenn.
Chet A. Kershaw, Portland, Ore.
Earl B. Lear, Utica, N. Y.
Stanley E. Malouf, Chibougamau, Que., Canada
Raul V. Pelaez, New York
Thomas C. Quackenboss, Holden, W. Va.
Clark B. Risler, Pittsburgh
Otto D. Rohlfs, Grand Junction, Colo.
Herbert H. Smith, Cleveland
Harold D. Webb, Edgemont, S. D.

Associates

Trevor Aston, Wilkes-Barre, Pa.
Thomas M. Childerhose, Kirkland Lake, Ont., Canada
Max E. Colson, Wilmington, Del.
Francis X. Farrell, Wilkes-Barre, Pa.
George A. Franz, Knoxville, Tenn.
Robert D. Ganley, Hurley, N. M.
Robert G. Kenly, New York
Denison Kitchel, Phoenix, Ariz.
Norman S. McHarg, Las Vegas, Nev.
James C. O'Kelley, Carlsbad, N. M.
David M. Rankin, Kirkland Lake, Ont., Canada
Benj. F. Schaberg, Devon, Pa.

Juniors

Tura M. Aldous, Salt Lake City
Nicholas Apostolidis, Athens, Greece
Krishan K. Batra, Stoke-on-Trent, England
Harold G. Grant, Sudbury, Ont., Canada
Melvin Irvin, Pueblo, Colo.
Lelon E. Lewis, Grand Junction, Colo.
Ernest Simpson, Grand Junction, Colo.
Philip S. Wein, Grand Junction, Colo.

CHANGE OF STATUS

Associate to Member

Dale C. Brittain, Tucson, Ariz.
Jacob M. Lebeaux, Houston

Junior to Member

Leroy K. Wheelock, New York

REINSTATEMENT

Members

James E. Kuykendall, Grand Junction, Colo.
Wesley I. Stonebraker, Peckville, Pa.

Junior

Richard B. Johnson, Birmingham

REINSTATEMENT—CHANGE OF STATUS

Junior to Member

Robert W. Ageton, Arlington, Va.

Student to Member

Roger R. Nelson, Madison, Wisc.

Student to Junior

Chester E. Miller, El Paso, Texas

Coming Events

Sept. 22, AIME, Adirondack Local Section, visit to Appalachian Sulphides, South Strafford, Vt. Dinner, Lake Morey Inn, Fairlee, Vt.

Sept. 26-28, AIME Rocky Mountain Minerals Conference, Newhouse Hotel, Salt Lake City. Technical papers will represent all branches, including the Petroleum Div.

Oct. 1-4, American Mining Congress, Mining Show, Shrine Auditorium, Los Angeles.

Oct. 6, AIME, Upper Peninsula Section, Mather Inn, Ishpeming, Mich. Annual meeting, field trips, and President's reception and banquet.

Oct. 8-10, AIME, Institute of Metals Div., Carter Hotel, Cleveland.

Oct. 8-12, UPADI, fourth convention, Hotel del Prado, Mexico City, Mexico.

Oct. 11-13, University of Minnesota, Annual Drilling Symposium, Center for Continuation Study, University of Minnesota, Minneapolis.

Oct. 14-17, AIME, Petroleum Branch, Biltmore Hotel, Los Angeles.

Oct. 22-24, ASA, 38th annual meeting, Hotel Roosevelt, New York.

Oct. 25, 26, AIME-ASME Joint Solid Fuels Conference, *Future Role of Solid Fuels in an Expanding Economy,* Sheraton-Park Hotel, Washington, D. C.

Oct. 25-26, ECPD 24th Annual Meeting, Engineering Society of Detroit at Statler Hotel, Detroit.

Oct. 29-Nov. 1, Society of Exploration Geophysicists, 26th annual meeting, Hotel Roosevelt, New Orleans.

Oct. 31-Nov. 2, Gulf Coast Assn. of Geological Societies, sixth annual convention, Plaza Hotel, San Antonio, Texas.

Nov. 1-3, Geological Society of America, annual meeting, Minneapolis.

Nov. 1-3, New Mexico Mining Assn. and International Mining Days, Carlsbad, N. M.

Nov. 2-3, AIME Central Appalachian Section and Petroleum Subsection, Fall Meeting. (Joint meeting with West Virginia Coal Mining Institute.) Greenbrier, White Sulphur Springs, W. Va.

Nov. 3, AIME, Adirondack Local Section, football game, Syracuse, N. Y.

Nov. 8-10, AIME, Northeastern Mining Branch Conference, Hotel Hershey, Hershey, Pa. Lehigh Valley Section is host.

Nov. 11-14, Society of Exploration Geophysicists, 27th Annual Meeting, Statler-Hilton Hotel Dallas.

Nov. 12, 13, Joint Symposium on Mining Research. Missouri School of Mines and USBM, Rolla, Mo.

Nov. 12-15, Amer. Petroleum Inst., annual meeting, Conrad Hilton Hotel, Chicago.

Dec. 5-7, AIME, Electric Furnace Steel Conference, Hotel Morrison, Chicago.

Feb. 7-9, 1957, Colorado Mining Assn., Denver.

Feb. 24-28, AIME Annual Meeting, Roosevelt and Jung Hotels, New Orleans.

Mar. 10-16, EJC Second Nuclear Engineering and Science Congress, Convention Hall, Philadelphia.

Apr. 1-4, Amer. Assn. of Petroleum Geologists, annual meeting, Kiel Auditorium, St. Louis.

Apr. 8-10, AIME National Open Hearth Steel and Blast Furnace, Coke Oven, and Raw Materials Conferences, William Penn Hotel, Pittsburgh.

Apr. 11-13, AIME, Pacific Northwest Regional Conference, Portland, Ore.

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